INSTRUCTIONS

JEM-1200EX

ELECTRON MICROSCOPE

JEOL

No. IEM1200EX-2
(EM157012)

Filament change
6-5

JEOL LTD. / 日本電子

F5 (After chapter 6)
Finding Electron beam.

Tokyo Japan

8309081HP

To the user:

This instruction manual covers the operating procedures for the basic JEM-1200EX Electron Microscope. That is to say, if the instrument delivered to your institution has been modified in any way to satisfy your specific research requirements, certain aspects of the manual will require certain (minor) amendments. If in any doubt, please contact your nearest JEOL Service Center.

AMENDMENTS TO INSTRUCTION MANUAL

JEM-1200EX

No. CI1EM1200EX-2
(EM157012)

The instrument has undergone certain modifications in order to improve performance and facilitate operation. Please, therefore, note the following changes and correct your manual accordingly. We regret any inconvenience caused.

1. Although the parts listed below are optional accessories, they are described as standard items in this manual for the sake of convenience. They are: anti-contamination device, refrigerant funnel, refrigerant drainer, beam stopper, specimen grid case, hexagonal screwdrivers, activated alumina trap and tweezers.
2. Some controls on control panel L1 have been changed as follows:

   L1- ⑨ : ROOM LIGHT: Used for turning on/off the room light.

   L1- ⑩ : BRIGHT ZOOM: For the zoom circuit (see Subsect. 5.2.11q).

   L1- ⑪ : BRIGHT 16×: When this button is switched on, the button lamp lights up and the 2nd condenser lens current range, variable by the BRIGHTNESS knob (control panel L1), enlarges 16 times.
3. To set the magnification when the MAG2 button (control panel R1) is depressed (this magnification is called "basic magnification") at 5,000 times, refer to Subsect. 5.2.11r.
4. The name of the knobs, IW ADJ, on control panel R2 has been changed to "IMAGE WOBBLER ADJ".
5. The names of the keys, C/R, ◀ and ▶, on the keyboard have been changed to "RETURN", "←" and "→" respectively.
6. Change Steps 8 and 9 in Subsect. 6.1.2 as follows:

   Step 8: Depress the GUN AIR button (L2-4). Air is admitted into the anode chamber.

   Step 9: Make sure that the PI2 value (indicated on PAGE-1) has increased to 250, then turn the LIFT switch (L2-1) to ON.
7. Change Steps 2 and 3 in Subsect. 6.7.7b as follows:

   Step 2: Make sure the electron gun has not been lifted and camera chamber door is closed.

   Step 3: Switch off the COL AIR button (L2-5).
8. In Subsect. 6.8, add another step, Step 19, after Step 18.

   Step 19: Make the objective lens pole piece name displayed on PAGE-1 coincide with the name of the pole piece being installed in the objective lens (see Subsect. 5.2.11e).
9. The aperture disk and aperture holder of the Wehnelt assembly have been removed.
10. Two types of objective lens aperture, 20-50-80 $\mu m\phi$ aperture for the SHP pole piece and 50-100-150 $\mu m\phi$ aperture for the SAP pole piece, have been provided.

11. Correct the related items as follows:

Page	Line	Before amendment	Amended to
3-7	Fig. 3.3-2	Image wobbler coil	Spot alignment coil
3-9	Fig. 3.4-2	V22	V18
3-10	Fig. 3.4-3	Turbomolecular pump	Turbomolecular pump or oil diffusion pump
4-8	22 ~ 23	. . . image wobbler coil . . . beam deflector coil	. . . the 1st and 2nd beam deflector coils
4-9	30	. . . a magnification of 5,000X is obtained.	. . . the basic magnification (generally 5,000X) is obtained.
4-9	32	from 5,000X with . . .	from the basic magnification with . . .
5-1	18 ~ 19	vacuum system . . . restored.	instrument is not restored to its original state.
5-17	17	Depress the SP PO key (KB-1) and . . .	Obtain PAGE-2 with the PAGE key (see Subsect. 5.2.11a) and . . .
5-21	14 ~ 15	. . . , repeatedly depress the MAG . . . displayed.	. . . , display the same pole piece name, referring to Subsect. 5.2.11e.
5-24	8	Depress . . . (L1-10).	Set to the OUF mode (Subsect. 5.2.11o).
5-24	9	By using this switch . . .	By using this mode . . .
5-63	16	. . . the large condenser . . .	. . . the smallest condenser . . .
6-12	1	. . . pump oil replacement	. . . pump (when the EM-TMP is used)
6-12	2	The pump oil . . . 5,000 hours.	When pump operation has exceeded 5,000 hours the pump oil, and when it has exceeded 20,000 hours the bearings must be replaced.
6-24	8	5.2.6), and . . .	5.2.6).
6-25	Step 7	. . . one hour more.	. . . three hours more.
F-14		Condenser aperture . . . largest	Condenser aperture . . . smallest
F-17		Leave for 1 hour	Leave for 3 hours

CONTENTS

[FLOWCHARTS]

1. GENERAL

1. GENERAL

1.1 Introduction

The JEM-1200EX is a versatile state-of-the-art high resolution electron microscope that can function either as a combined electron microscope or an analytical electron microscope. When used in conjunction with a scanning attachment and analytical facilities, it functions as a combined electron microscope or analytical electron microscope, and fully exhibits its capacity as a composite instrument or an analytical instrument, providing various useful information on the specimen.

With a view to obtaining accurate information from the specimen, special attention has been paid to improvement of the specimen environment. The dry pumping system and minimum electron dose system are built-in to achieve this purpose. It goes without saying that various new design concepts are incorporated in the optical system. The advanced imaging-lens system minimizes image rotation due to magnification change, curtailment of field of view, and off-axial aberration.

Through keyboard operation, the optical system can be freely controlled and a specific condition can be stored in memory and read out. Operating condition data can also be displayed on CRT and part of it printed on film. Write-in of user's comments and storing them in memory are also possible through keyboard operation. The troublesome alignment procedure has been greatly simplified because axial alignment procedure is displayed step by step on CRT and the lens excitation conditions required for operation are automatically set.

These outstanding features make the JEM-1200EX the most advanced total optimum performance system.

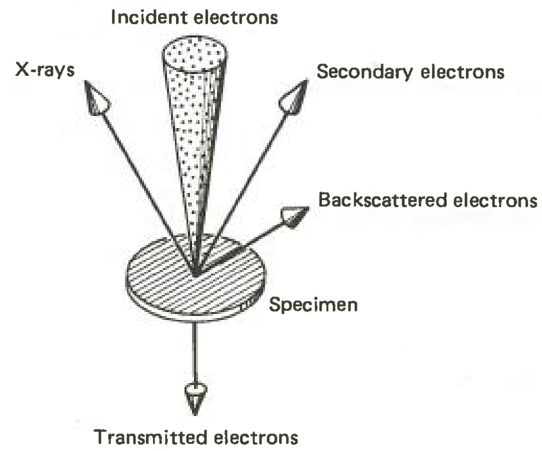


Fig. 1.1 Signals generated by interactions between electron beam and specimen

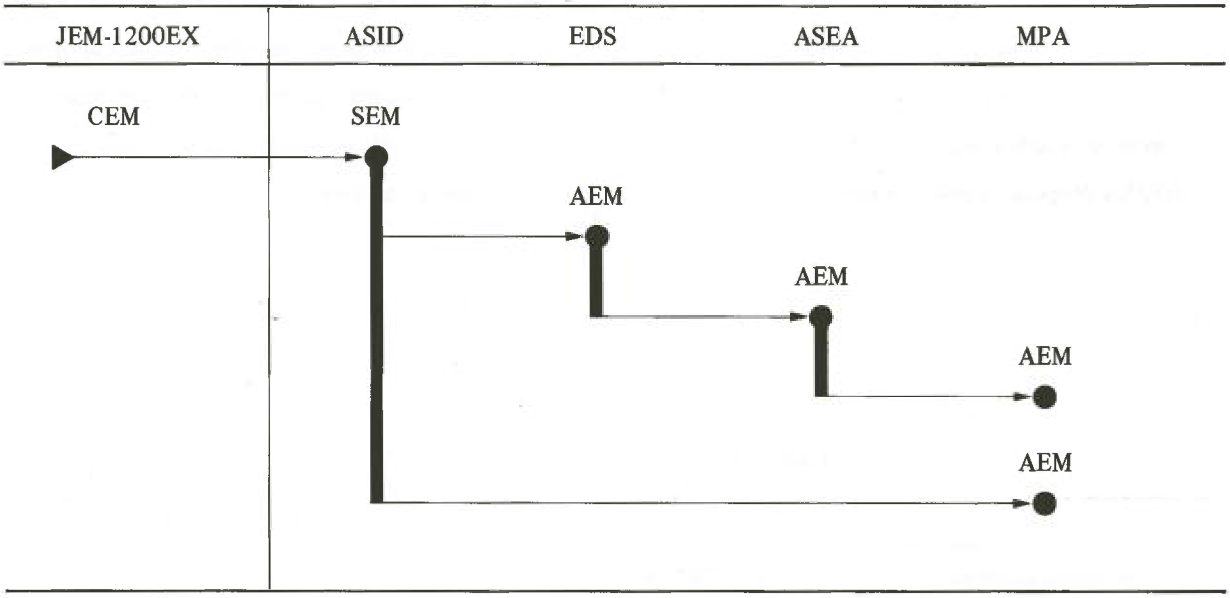
The main attachments and possible combinations are described in the following tables. For details of attachments not listed, refer to the relevant specifications and catalogues.

Table 1.1 Main attachments

Abbreviated designation	Full designation	Description
TEG	Top entry goniometer	Permits direct imaging of crystalline specimens with atomic-level resolution, examination of lattice defects, etc.
ASID	Scanning image observation device	This attachment permits high resolution secondary electron images and transmission scanning images to be obtained simultaneously. The field of its use is widened when various detectors or signal processors are used in conjunction.
EDS	Energy dispersive X-ray spectrometer	This spectrometer permits simultaneous elemental analysis of a micro-area by highly efficient X-ray detection.
ASEA	Electron energy analyzer	This high resolution electron energy analyzer permits elemental analysis in a micro-area of the specimen (especially effective for light element analysis) as well as analysis of its chemical state.
AD	High resolution electron diffraction stage	Provides transmission electron diffraction patterns in the case of ordinary specimens and reflection electron diffraction patterns in the case of bulk specimens. The High Resolution Electron Diffraction Hot Stage, the High Resolution Electron Diffraction Cold Stage and AND Charge Neutralizer are also available.
AMG	Magnetic material observation device	This device permits observation of transmitted electron images of magnetic materials and magnetic domains free from lens field influence.
DFI	Dark field imaging device	Used in conjunction with ASID, this unit provides STEM mode dark field images with a comparatively low electron beam current. Effective for observing unstained biological specimens.
DSC	Film desiccator	Camera chamber evacuation time is shortened when films are dried in the desiccator prior to putting them in the electron microscope camera chamber.

Abbreviated designation	Full designation	Description
FLC	Free lens control unit	For independent control of the lens excitation current which is usually preset. The memory unit of the instrument can store in the memory the value and reproduce it.
LBG	LaB_6 cathode electron gun	Brightness 5–10 times that of conventional electron guns is obtained by use of the LaB_6 cathode.
MPA	Micro-particle analyzer	Measures precipitate distribution, particle distribution, particle diameter and particle area from the scanning image.

Table 1.2 Electron microscope system



AEM: Analytical electron microscope CEM: Conventional electron microscope SEM: Scanning electron microscope

1.2 Principle of electron microscope

Electron microscopes are widely used today and can be effectively handled without any knowledge of the principle involved. The JEM electron microscope, being fully automated and simple to use, is no exception. Thus, high performance is assured for every user, regardless of his level of skill. Even so, a rudimentary knowledge of how a microscope works, its structure, etc. is a distinct advantage. What follows is an attempt to fill this need in a simple, concise fashion. Accordingly, if the user is familiar with the basic principles of electron optics and image formation, he may proceed to Chapter 2.

1.2.1 General principles

1.2.1a Comparison between electron microscope and optical microscope

Fundamentally and functionally, electron microscopes (EM) and optical microscopes (OM) are identical. That is, both types of microscope serve to magnify minute objects normally invisible to the naked eye. The basic difference between the two, however, is that an electron microscope uses an electron beam as a specimen illuminating medium whereas an optical microscope uses a light beam (including ultraviolet rays) for this purpose. Table 1.3 lists the main differences between the EM and OM.

Table 1.3 EM and OM comparison chart

	Electron microscope	Optical microscope
Illuminating beam	Electron beam	Light beam
Wavelength	0.0086 nm (20kV) ~ 0.0025 nm (200kV)	750 nm (visible) ~ 200 nm (ultraviolet)
Medium	Vacuum	Atmosphere
Lens	Electron lens (magnetic or electrostatic)	Optical lens (glass)
Aperture angle	~ 35′ ~	~ 70°
Resolving power	Point to point: 0.35 nm, lattice: 0.14 nm	Visible: 200 nm, ultraviolet: 100 nm
Magnification	100X ~ 1,000,000X (continuously variable)	10X ~ 2,000X (lens exchange)
Focusing	Electrically	Mechanically
Contrast	Scattering absorption, diffraction, phase	Absorption, reflection

Since the illuminating beam of an electron microscope is an electron beam and the medium is vacuous, there are certain limitations. However, by effectively using a wealth of attachments, many advantages can be realized. This is especially true when the microcope combines scanning image microscopy, electron diffraction and X-ray analysis. Basically, component terminology of an electron microscope is similar to that of an optical microscope (shown in Fig. 1.2).

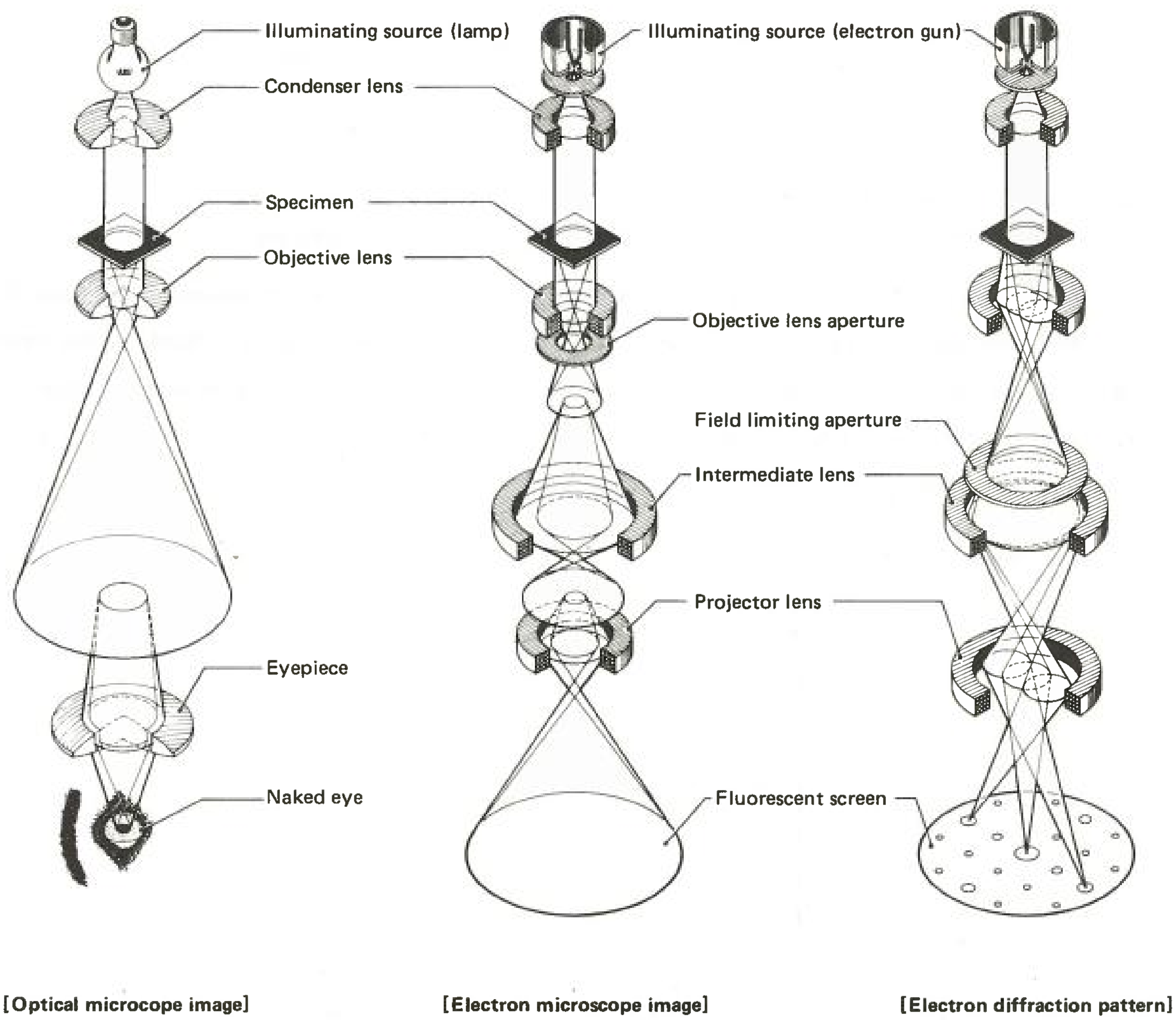


Fig. 1.2 Comparison of image formation

1.2.1b Resolving power and resolution

Image quality is usually shown by "resolving power" which is defined as the shortest distance between two points (or two lines) which can be recognized as two different images. However, this term has two different meanings: the resolving power of the instrument and the resolution of the micrograph. It is important that this difference be thoroughly understood.

In the case of the optical microscope, the resolving power, d, is determined by diffraction aberration as follows:
Spherical aberration and chromatic aberration can be removed almost completely;

$$d = \frac{0.61\lambda}{\mu \sin\alpha} = \frac{0.61\lambda}{NA} \quad \cdots\cdots (1)$$

where λ: Wavelength of light, α: Aperture angle
μ: Refractive index of the object space, NA: Numerical aperture

On the other hand, electron microscopes are influenced by spherical aberration, which cannot be effectively corrected at present. Therefore, the electron beam near the axis must be utilized and the resolving power of the electron microscope determined by a combination of spherical aberration and diffraction aberration as illustrated in Fig. 1.3. O. Scherzer has calculated the limit of resolving power d_{min} and its objective lens aperture angle α_{opt}:

$$d_{min} = 0.43\sqrt[4]{\lambda^3 C_s} \quad \cdots\cdots (2)$$

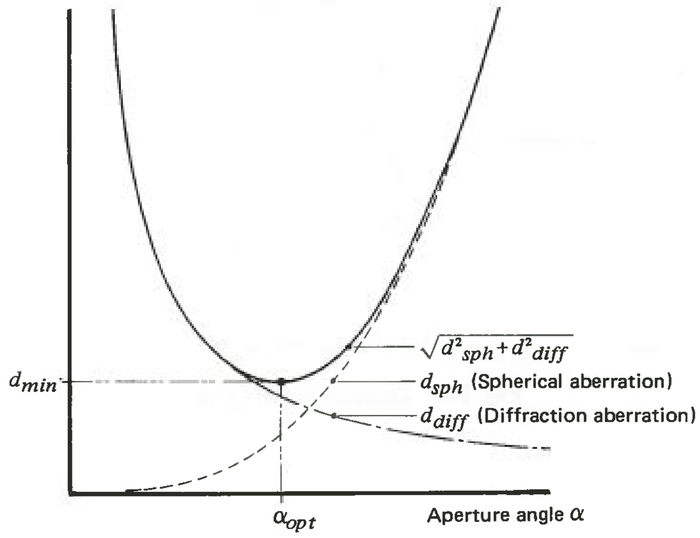


Fig. 1.3 Limit of resolving power

$$\alpha_{opt} = 1.41 \sqrt[4]{\lambda / C_s} \quad \text{.......................................} \quad (3)$$

where λ: Wavelength of the electrons
C_s: Spherical aberration coefficient of the objective lens

This equation is predicated on the assumption that only spherical aberration and diffraction aberration exist. However, the influence of factors such as chromatic aberration cannot be disregarded in electron microscopy. As mentioned earlier, the removal of aberrations from electron microscopes is much more difficult than in the case of optical microscopes, but with the former a high resolving power can be obtained since the wavelength of electrons is very short, i.e., approximately 1/100,000 of the wavelength of light rays. The wavelength of the electrons λ is usually determined by the accelerating voltage V. And, since the accelerating voltage of an electron microscope is on the order of several tens of kilovolts or higher, corrections based upon the effect of relativity must be taken into consideration in order to calculate the wavelength of the electrons, the equation for which is given as follows:

$$\lambda = \frac{1.2261}{\sqrt{V} \cdot \sqrt{1 + 9.7880 \times 10^{-7} \cdot V}} \text{ [nm]} \quad \text{..........................} \quad (4)$$

Compared with the resolving power of a microscope, the resolution of a micrograph is inferior because of specimen, microscopic and photographic conditions. Accordingly, in order to obtain the best resolution, special attention should be given to specimen preparation, microscopy operation, photographing, the maintenance of the microscope (routine inspection and cleaning), and photographic processing.

To determine the resolving power d visually, a suitable magnification is required. The minimum effective magnification M is determined by the resolving power of the eye d_1, (approx. 0.1 mm) thus,

$$M = \frac{d_1}{d} \quad \text{..} \quad (5)$$

Accordingly, if we assume that the resolving power of an electron microscope and that of an optical microscope are 0.2 nm and 200 nm, respectively, then the effective magnifications for these microscopes will need to be 500,000× or more and 500× or more, respectively.

To ascertain the resolving power, the image to be observed is photographed at a magnification slightly lower than the calculated one and the photographs then enlarged. And since photographs obtained with an electron microscope have a resolution d_2 (approx. 20 μm under good conditions), the required minimum photographic enlargement magnification M_1 is 5×, which is calculated as follows:

$$M_1 = \frac{d_1}{d_2} \quad \text{..} \quad (6)$$

However, an enlargement of more than 5× is even more helpful, since this would allow for a lower d_1.

1.2.1c Principle of the electron lens

Since electron microscopes use an electron beam as an illuminating medium, it follows that electron lenses are used to irradiate the specimen and form the image to be observed. Electron lenses are usually classified into magnetic and electrostatic lenses (employing axially symmetric magnetic and electric fields, respectively) and special purpose electron lenses such as quadrupole lenses. However, since ordinary electron microscopes normally employ magnetic lenses, the following description concerns itself with that type only.

If, when an electron passes through a magnetic field, the direction of the electron is identical to that of the magnetic field, the electron is not subjected to any external force. If, on the other hand, the direction of the electron is perpendicular to that of the magnetic field, the electron is subjected to a force such that the electron travels on a plane perpendicular to the plane which includes the direction of the electron and that of the lines of magnetic force. Moreover, if the intensity of the magnetic field is uniform, the orbit of the electron on the plane will form a circle. In this case, the radius r of the circle can be calculated as follows: Since the force on the electron moving with a velocity v is evB and the centripetal force is $\frac{mv^2}{r}$ (Fig. 1.4a).

$$r = \frac{mv}{eB} = \frac{v}{\eta B} \quad \cdots\cdots (7)$$

where
- m: Mass of electrons
- v: Velocity of electrons
- e: Electric charge of electrons
- B: Magnetic flux density
- η: Specific charge of electron e/m

As this equation illustrates, if the magnetic flux density is uniform, the radius of the circular orbit formed by the electron, which crosses the magnetic field at right angles, is proportional to the velocity of the electron.

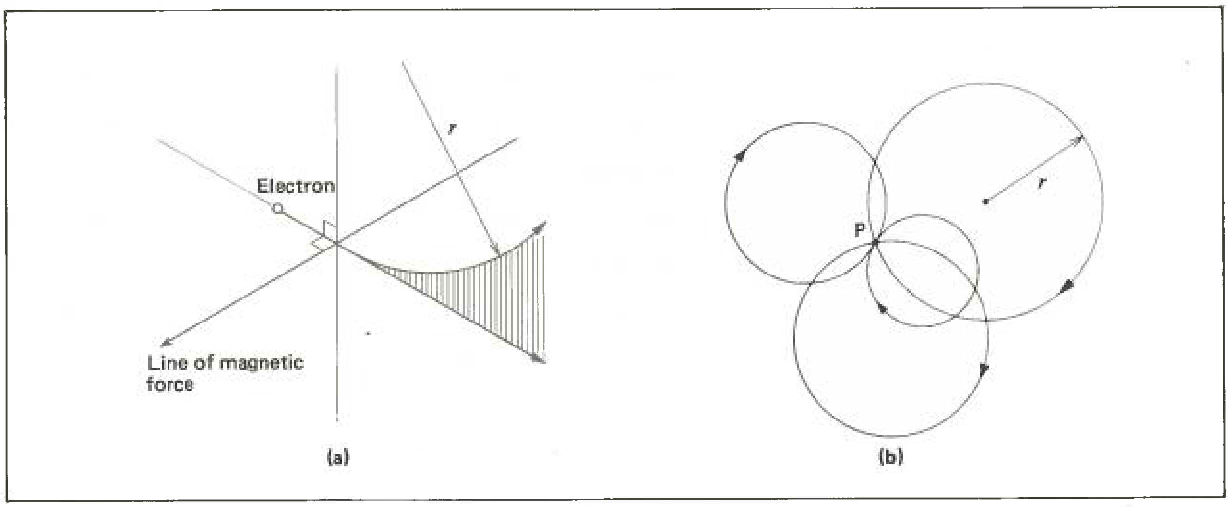


Fig. 1.4 Electron trajectories

When several electrons are simultaneously emitted at different velocities and directions from point P on a plane perpendicular to the uniform magnetic field, each electron forms a circular orbit with a radius proportional to its velocity and returns to point P as illustrated in Fig. 1.4b. The time τ required for one revolution is given as follows:

$$\tau = \frac{2\pi r}{v} = \frac{2\pi}{\eta B} \quad \text{.......................................} \quad (8)$$

Accordingly, a uniform magnetic flux density provides a constant period, τ, and all the electrons emitted at a given time return to the original point P simultaneously, i.e., the angular velocity is always constant.

When an electron is emitted obliquely with respect to the lines of magnetic force in a uniform magnetic field, the electron forms a helical orbit, a phenomenon attributable to a uniform motion along the lines of magnetic force and a circular motion perpendicular to the lines of magnetic force. As shown in Fig. 1.5, when an electron is emitted from point P at a velocity v and at an angle α with respect to the direction of the uniform magnetic field H, the electron travels along helical orbit a. This is due to a uniform motion caused by the velocity component v_x and a circular motion caused by the velocity component v_y. The electron then passes through point P′ on the line of magnetic force containing the original point, P. Since $v_y = v \sin \alpha$, the radius r of the circular orbit can be rewritten as follows:

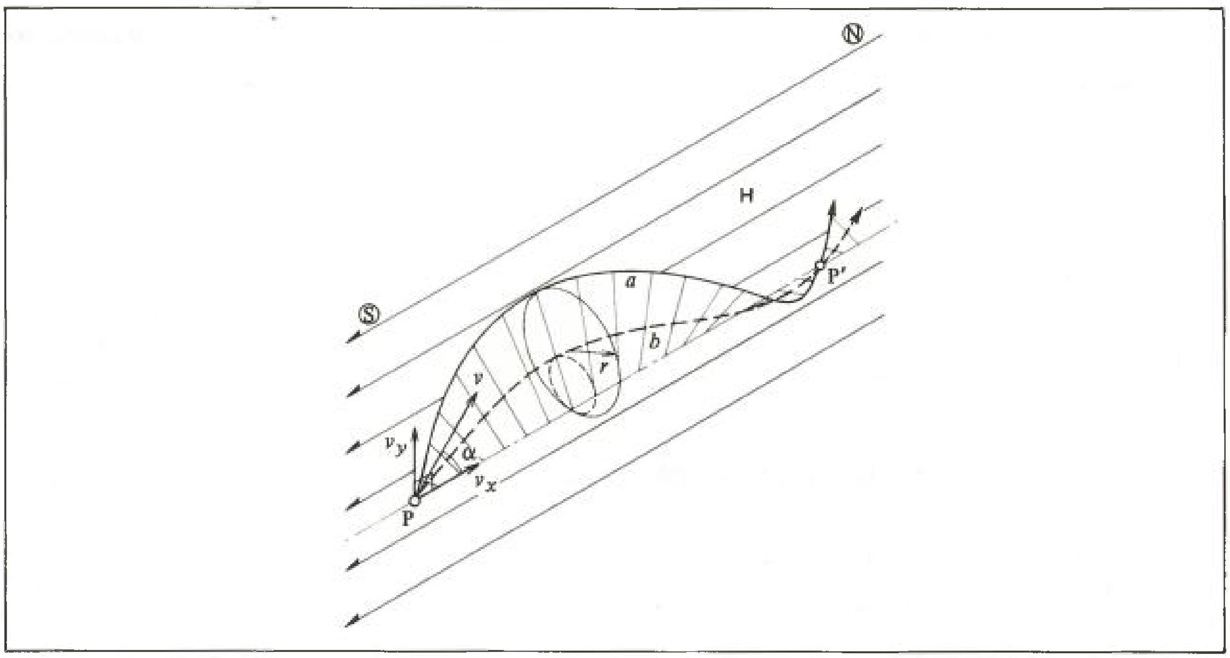


Fig. 1.5 Trajectories of electrons emitted obliquely in a uniform magnetic field

$$r = \frac{v}{\eta B} \sin\alpha \quad \text{.......................................} \quad (9)$$

Since generally, in electron microscopes, electron beams near the axis are used for forming an image, α is extremely small (refer to Table 1.3, Aperture angle). Therefore, the velocity component of an electron parallel to the lines of magnetic force can be given as follows:

$$v_x = v \cos\alpha \fallingdotseq v \quad \text{...................................} \quad (10)$$

When two electrons are emitted simultaneously from point P at different angles, they orbit a and b and reach point P′ at the same time. That is, it is possible to form an image in a uniform magnetic field. Distance d, between points P and P′ on the same line of magnetic force, is the distance between nodal points and is calculated as follows:

$$d = v_x T = \frac{2\pi v}{\eta B} \quad \text{......................................} \quad (11)$$

When this equation is compared with Equation (7), it will be found that d is equal to the circumference of the circular orbit described by an electron having a velocity v perpendicular to the line of magnetic force. Fig. 1.6 shows the orbits of electrons in a vacuum. All the electrons emitted from the same point, P, converge at the same point, P′, through respective paths. The effect of this is similar to that of optical convex lenses. However, there is an obvious difference in that all parallel light rays which are incident to an aberration-free optical lens converge on the back focal plane, whereas electrons emitted in a uniform magnetic field do not converge.

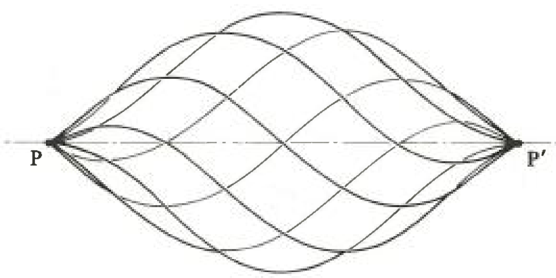


Fig. 1.6 Electrons passing through a uniform magnetic field

There are three types of magnetic lenses in use: (1) a multi-layer coil, i.e., an air-core solenoid coil (refer to Fig. 1.7a), (2) a coil enclosed by soft iron plates (in order to reduce leakage flux) containing a gap (in order to concentrate the induction field) (refer to Fig. 1.7b), and (3) a coil enclosed by soft iron plates containing a gap and internal soft iron pole pieces (in order to ensure a high intensity magnetic field) (refer

to Fig. 1.7c). Almost all modern electron microscopes use pole pieces for high resolving power and high magnification. The function of such an electron lens is more or less the same as that of horse-shoe magnets symmetrically arranged about an axis. Accordingly, all the parallel electron beams incident to the curved magnetic field converge at one point.

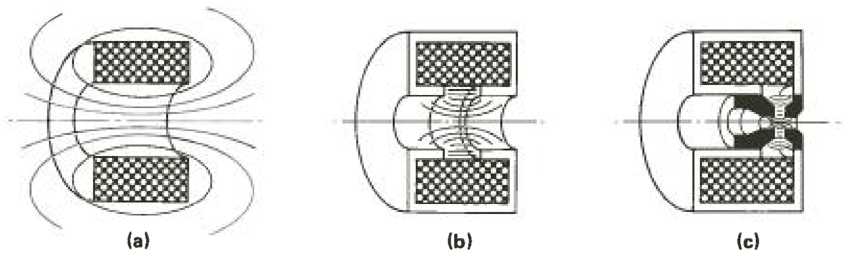


Fig. 1.7 Types of magnetic electron lenses

Fig. 1.8 shows the trajectory of an electron passing through such a magnetic field. Although the electron beam path in a magnetic lens is not the same as the light ray path in an optical lens, the results are similar. As shown in Fig. 1.8, the electron travels rectilinearly, crosses the axis, moves through the magnetic field along a spiral orbit, approaches the axis, crosses the axis again, and travels rectilinearly. This effect is similar to the converging action of an optical convex lens, and if the revolution of the electron about the axis is omitted, the converging action of an electron lens can be considered to be identical to that of an optical lens.

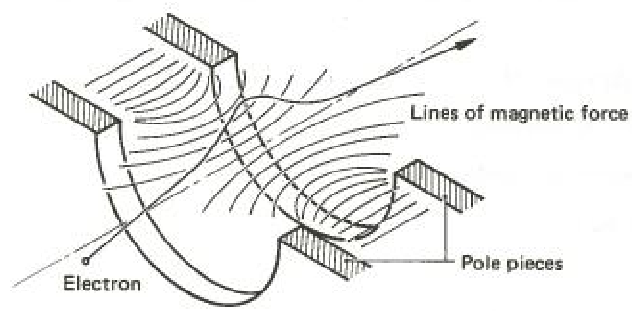


Fig. 1.8 Electrons passing through magnetic lens

A magnetic lens containing pole pieces magnetized to near-saturation for concentrating magnetic

flux in a very narrow space constitutes a thin lens. The magnetic field distribution and image formation graphs are illustrated in Fig. 1.9. The focal length f and rotation angle θ are given as follows:

$$\left.\begin{aligned} \frac{1}{f} &= \frac{\eta}{8V}\int_{-\infty}^{+\infty} B^2(x)\,dx \\ \theta &= \sqrt{\frac{\eta}{8V}}\int_{-\infty}^{+\infty} B(x)\,dx \end{aligned}\right\} \cdots\cdots (12)$$

where V: Accelerating voltage

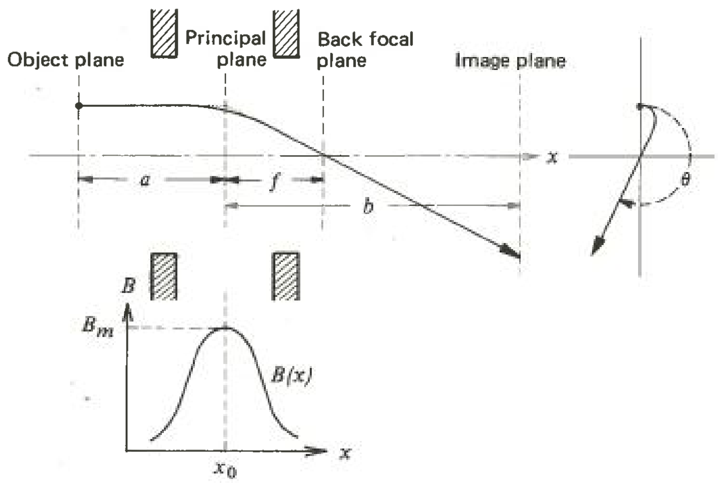


Fig. 1.9 Magnetic field distribution and image formation graphs

As known from Equation (12), shortening focal length f requires an increase in magnetic flux density B; moreover, since $B \propto NI$ (ampere-turns), current for the coil must be increased to obtain a short focal length. Since the aforementioned electron lens has the same effect as an optical thin convex lens, the following equations are obtained:

$$\left.\begin{aligned} \frac{1}{a} + \frac{1}{b} &= \frac{1}{f} \\ M &= \frac{b}{a} \end{aligned}\right\} \cdots\cdots (13)$$

where M: Magnification

1.2.1d Interaction between electron beam and substances

When an electron beam passes through a substance, the beam is scattered due to coulomb interactions, the direction of movement is changed and a partial energy loss takes place.

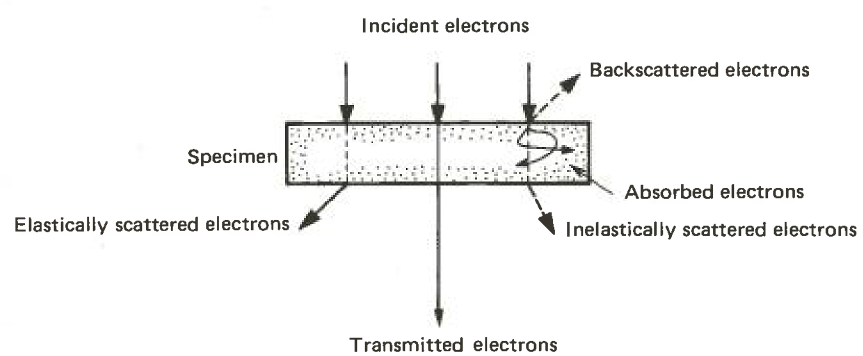


Fig. 1.10 Interaction between electrons and substances

As shown in Fig. 1.10, when electrons having a given energy impinge on a substance, they are changed into transmitted electrons, backscattered electrons (reflected electrons) and absorbed electrons (energy absorption) by the interaction of the aggregate of the atoms constituting said substance. The transmitted electrons can be classified into three types: 1) directly transmitted electrons (transmitted wave), which pass through the specimen with little change of direction or wavelength, 2) elastically scattered electrons (elastically scattered waves), which undergo a directional change due to atomic collision but retain their energy, and 3) inelastically scattered electrons (inelastically scattered waves) which undergo both a directional change and a partial energy loss.

The ratio of the directly transmitted electrons to that of elastically scattered electrons is related to the contrast of images in transmission electron microscopy. The contrast of amorphous specimen images is primarily determined by mass thickness. Images of crystalline specimens are largely influenced by Bragg reflection. Inelastically scattered electrons may cause chromatic aberration in the image formation process. The absorbed energy, i.e., the energy which scattered electrons have lost while passing through the specimen, results in excitation of the atoms and atomic nuclei in the specimen. This causes heating, magnetization, ionization, secondary radiation (secondary electrons, Auger electrons, X-rays and cathodoluminescence) and plasma oscillation. When an incident electron has high energy, part of the energy may sometimes occasion radiation damage to the specimen by ejecting the atoms irreversibly from their normal positions in the specimen elastically. Although heat generation and ionization are the prime factors contributing to specimen

damage, they can be reduced by increasing the energy of the incident electrons. Backscattered electrons, which are sometimes called reflected electrons, scatter backwards with an energy comparable to the incident beam. The quantity of these electrons is determined by the specimen tilt angle and the atomic number of the element constituting the specimen.

1.2.1e Image formation and contrast

Image contrast is required in order to confirm the presence of an object and to study its configuration. If image contrast is unsatisfactory, it will be difficult to confirm the presence of an object, let alone study the configuration, even if the microscope has an extremely high resolving power. It therefore follows that the actual resolution of micrographs depends on image contrast to a very great extent.

In optical microscopy, image contrast is determined by the difference in the absorption coefficient at different points on the specimen and, to some extent, by the difference in reflectivity. However, in electron microscopy, image contrast is determined by scattering absorption contrast, diffraction contrast and phase contrast.

If the specimen is amorphous, the scattered electrons are absorbed by an aperture located near the back focal plane of the objective lens, thus producing scattering absorption contrast. This lens aperture has a very small diameter (several tens of μm) in order to minimize spherical aberration. Accordingly, if the scattering is large, most of the electrons will be blocked by the aperture, thus forming the dark portion of the image. The extent to which the electrons are scattered is proportional to the mass thickness of the specimen. Thus, the scattering absorption contrast provides information concerning the existence and configuration (topography) of the object as shown in Fig. 1.11.

In the figure, (a) shows the principle of contrast generation, (b) illustrates contrast generation in a specimen stained by a high density material (e.g., uranyl acetate or phosphotungstic acid), (c) shows an example of oxide film taken from the surface of a metallic specimen, and (d) shows an example of the shadow-casting technique, where a high density material is evaporated obliquely onto the replica film. Biological specimens are usually prepared by microtome sectioning and image contrast is obtained by directly staining the cellular tissue with osmium tetroxide, lead hydroxide, or uranyl acetate both before and after embedding or sectioning. Micro-specimens, such as viruses and cells, are usually processed by negative staining or by metal shadowing. The freeze-etching replica method is generally used in order to observe the cell surface and cell sections.

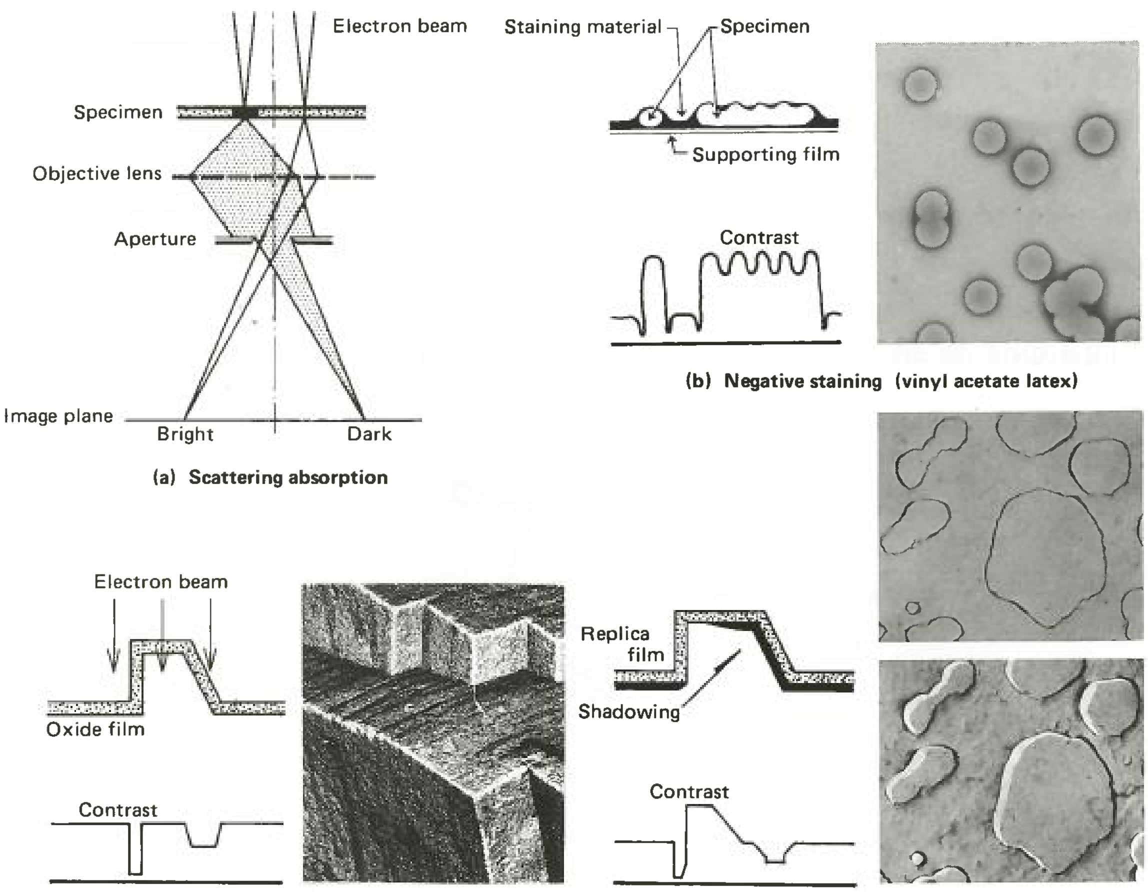
In the case of crystalline specimens, diffraction contrast appears as discussed below. If the atomic net planes in the crystal satisfy the following equation (Bragg equation):

$$2d \sin\theta = n\lambda \quad \ldots\ldots \quad (14)$$

where d: Interplanar spacing
θ: Grazing angle of incidence (Bragg angle)
n: Integer (0, 1, 2, 3 . . .)
λ: Wavelength of the incident electrons,

a diffracted beam results.

Since the spacing corresponding to the minimum Bragg angle of a simple metal or ionic crystal is approx. 0.5 nm, the diffraction angle 2θ, which is the angle subtended by the direction of incident electrons (incident waves) and that of the diffracted electrons (diffracted waves), is usually 5×10^{-3} rad or more. Accordingly, since almost all the Bragg-reflected electrons (namely, diffracted waves) are obstructed by the aperture, contrast as shown in Fig. 1.12a occurs. This image is known as "bright field image". On the other



(a) Scattering absorption

(b) Negative staining (vinyl acetate latex)

(c) Aluminum oxide replica

(d) Shadowed replica (cast iron)

Fig. 1.11 Scattering absorption (mass thickness) contrast

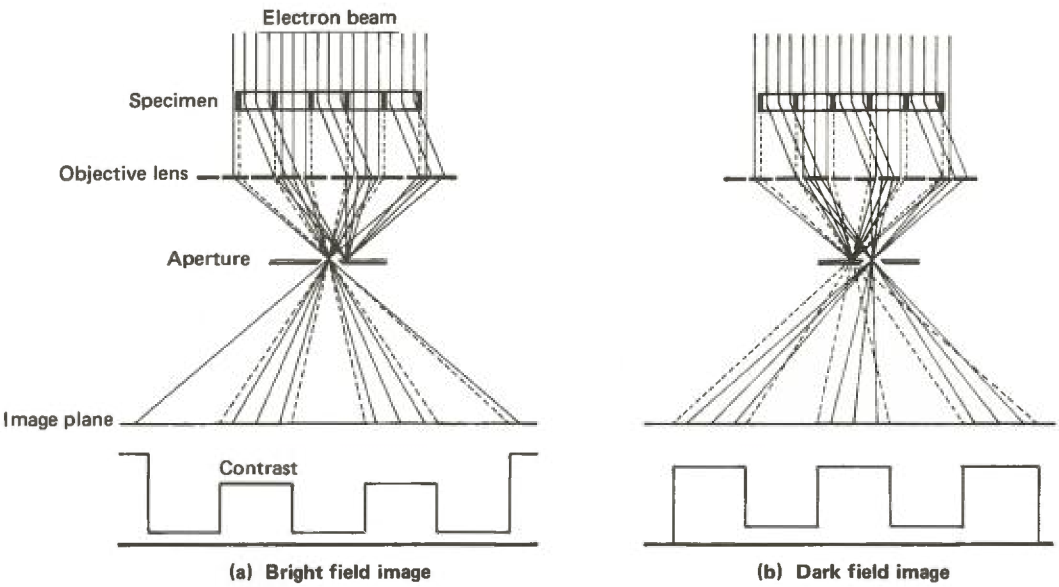


Fig. 1.12 Contrast in crystalline specimens

hand, when the aperture is shifted to obstruct the transmitted waves, so as to form an image by diffracted waves as shown in Fig. 1.12b, a so-called "dark field image" results. That is, dark field image contrast is usually achieved by inverting the contrast of the bright field image, except in cases where the crystal is very thick. If the crystal is curved, the reflection condition cannot be satisfied simultaneously over the entire area of the specimen.

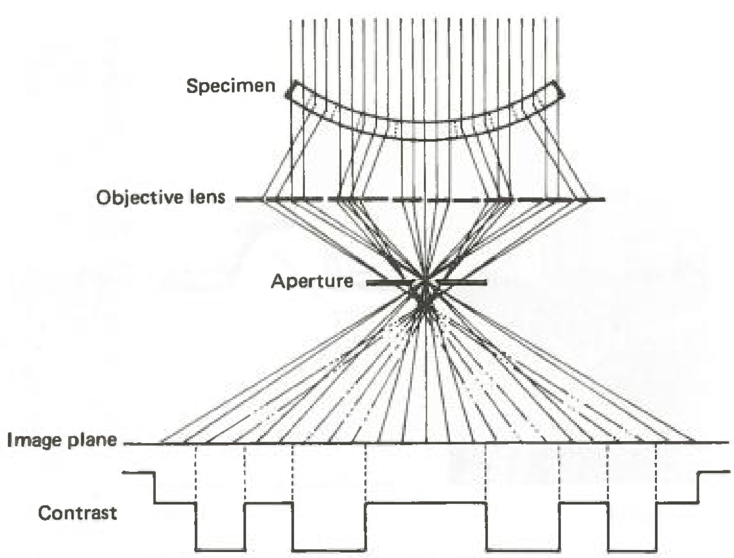
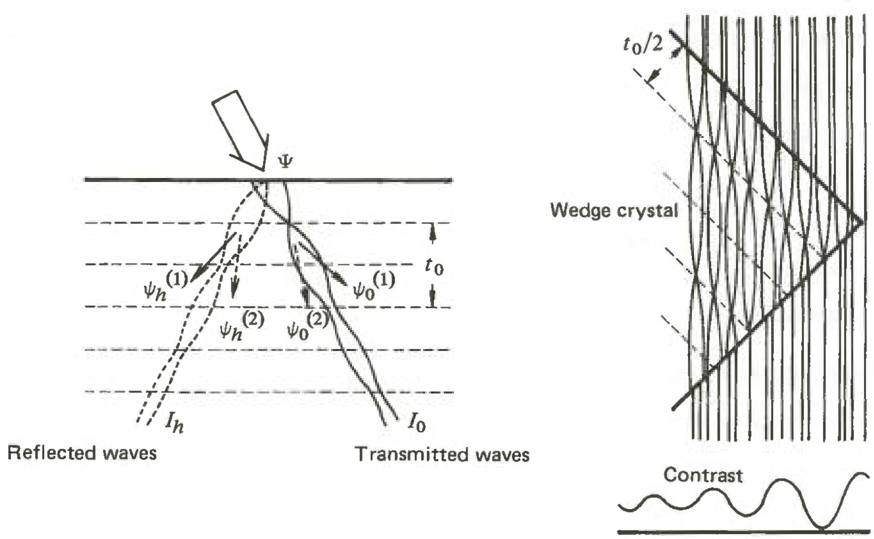


Fig. 1.13 Formation of equal inclination fringes

As a result, a fringe pattern, referred to as an "equal inclination fringe", appears as shown in Fig. 1.13. Electron beam illumination of a wedge crystal results in a fringe contrast referred to as an "equal thickness fringe". However, when the crystal takes the form of an exact cube (e.g., an MgO crystal), the reflection condition is satisfied over the entire area of the specimen. In this case, the entire crystal (according to simple kinematic theory) should be uniformly bright or dark. Fringe systems are recognized as follows:

When an incident wave Ψ enters a crystal, it is reflected at an atomic net plane having an index (hkl). Therefore, the intensity of the wave ψ_0 in the direction of the incident wave is decreased, and the intensity of wave ψ_h in the reflection direction is increased. The wave travelling in the reflection direction is reflected again at the atomic net plane $(\bar{h}\bar{k}\bar{l})$, and then advances in the original direction, increasing the intensity of the waves in the incident direction. Such intensity variation occurs repeatedly during passage through the crystal causing wave beats. Depth t_0, corresponding to the beat period, is called the "extinction distance" which depends upon the crystal, reflecting plane and the wavelength of the incident wave. The beat period of the reflected wave is delayed by a half period, compared with that of the transmitted wave. As illustrated in Fig. 1.14a, the above effect is caused by the interference of two transmitted plane waves $\psi_0^{(1)}$ and $\psi_0^{(2)}$, and two reflected plane waves $\psi_h^{(1)}$ and $\psi_h^{(2)}$ which are slightly different in direction and wavelength, respectively. When electrons are scattered by atoms, not only elastically scattered waves but also inelastically scattered waves are generated. When an electron penetrates far into a crystal, the beat amplitude (intensity) decreases. The influence of inelastic scattering forms a background at the amplitude nodes. Therefore, in the case of a wedge crystal (illustrated in Fig. 1.14b), intensity I_0 is equivalent to the beat cutting section of wave ψ_0



(a) Electron wave beats in crystal

(b) Equal thickness fringes

Fig. 1.14 Dynamical effect of electron waves

travelling in the incident direction. As a result, thickness fringes appear.

A crystal containing lattice imperfections provides a special contrast according to type (i.e., dislocations, stacking faults, voids, inclusion, etc.). When different types of precipitate exist, these lattice imperfections also result in special contrast. Since specimens contain a combination of these factors, complicated pattern contrasts are produced.

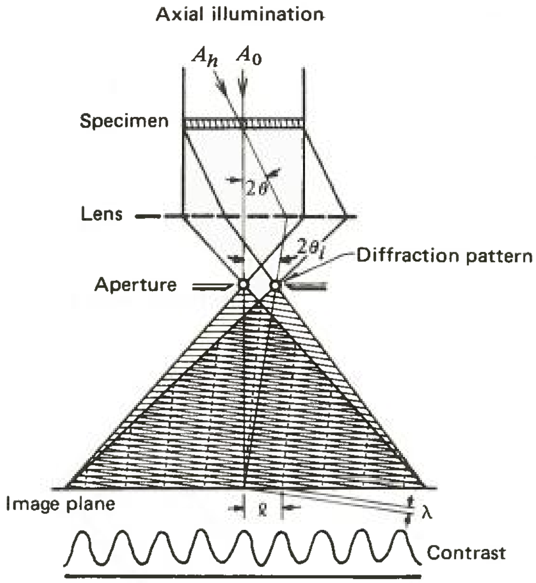
The contrast of extremely thin, small particles or low density specimens is determined mainly by phase contrast, instead of by scattering and absorption contrast. When electron waves of high coherence pass through a specimen, the phase of the waves becomes irregular due to scattering, lens aberrations, incorrect focusing and the internal potential of the substance. As a result, the intensity of the image forming waves on the image plane varies, a phenomenon which is referred to as phase contrast. Since phase contrast does not precisely correspond to the structure of the specimen, attention should be directed to the interpretation of the image obtained. Usually, the clearest images are obtained at slightly underfocus. In this case, the degree of under-focus is determined according to the substance and magnification used. However, excessive under-focus may cause misinterpretation of the image owing to the influence of Fresnel fringes.

Atoms in a crystal form a periodically regular lattice structure and, if the reflection condition is satisfied, the relation in Equation (14) will exist between spacing d (this value is very small as mentioned above), wavelength λ of the incident electrons and the grazing angle of incidence θ. Contrast formation different from that due to scattering and absorption may occur in images whose specimens have the aforesaid structure. That is, the interference of two or three waves, such as the reflected wave A_h and the transmitted wave A_0, or other reflected waves, causes a fringe pattern known as the lattice image. Fig. 1.15a illustrates the process of pattern formation: Electron beams are emitted along the axis, Bragg-reflected at the thin film crystal specimen, and the reflected and transmitted beams passing through the aperture overlap on the image plane, making a periodic pattern. In the figure, the distance ℓ between the adjacent interference fringes is given as follows:

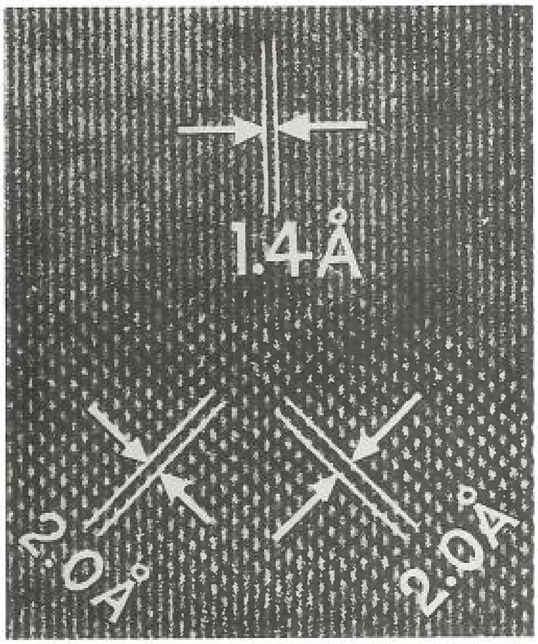
$$\ell = \frac{\lambda}{2 \sin \theta_i} = \frac{\lambda}{2 \sin \theta} M = M \cdot d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

where M: Magnification

As shown in this equation, ℓ is equal to the atomic net plane spacing multiplied by the magnification. Accordingly, this value is usually employed to represent the resolving power. However, lattice patterns are generally not greatly influenced by specific aberrations; this is especially so in the case of patterns obtained by tilted illumination. The actual interference fringes are complicated by other factors, such as crystal thickness, deviation from the Bragg condition, incorrect focusing, dislocation and secondary and tertiary diffracted waves. Fig. 1.15b illustrates the lattice pattern of a single crystal of gold. Diffracted waves from planes (220)



(a) Interference of two waves by axial illumination



(b) Lattice pattern showing single gold crystal planes (220) and (200)

Fig. 1.15 Image of specimen having periodic structure

and (200) are introduced through a lens aperture to form two interference fringe systems (0.14 nm and 0.2 nm) whose spacings are equal to the respective spacings of the lattice planes. Simultaneous use of the waves reflected by the rear plane in the case of axial illumination, in addition to the aforesaid waves, yields a half period pattern.

When an electron beam is incident with respect to two overlapping crystals, interference of the transmitted and double diffracted waves from the specimen results in a periodic pattern referred to as a "Moiré pattern". There are two fundamental types of Moiré pattern; one is the parallel pattern shown in Fig. 1.16b and the other is the rotation pattern shown in Fig. 1.16c. The parallel pattern is caused by double diffraction in the overlapped crystals, A and B, whose spacings, d_a and d_b, differ slightly. Satellite m and direct spot o are used through an aperture for Moiré pattern formation. On the other hand, the rotation pattern results from double diffraction in overlapped crystals having equal spacings but whose net plane directions differ (rotation angle α).

Spacing d_m for the parallel pattern is given as follows:

$$d_m = \frac{d_a d_b}{d_a - d_b} \quad \cdots\cdots \quad (16)$$

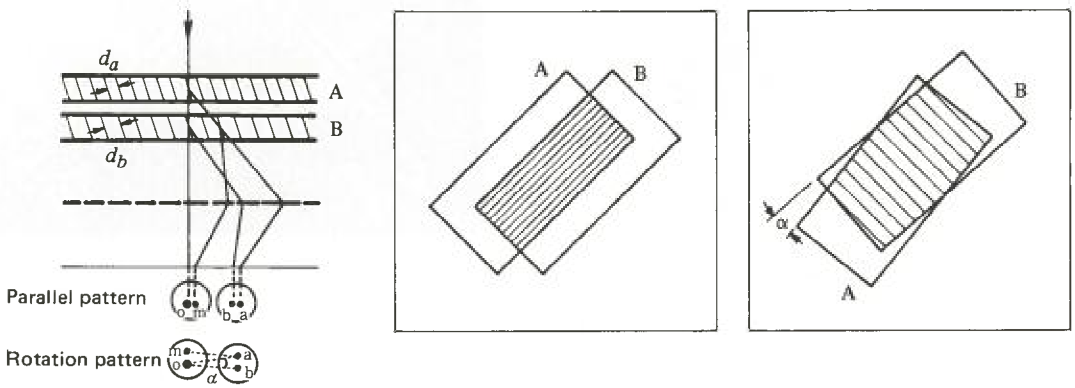
The spacing for a rotation pattern when $d_a = d_b = d$ is:

$$d_m = \frac{d}{\alpha} \quad \text{(17)}$$

The spacing for mixed pattern is calculated as follows:

$$d_m = \frac{d_a\, d_b}{\sqrt{(d_a - d_b)^2 + d_a\, d_b \cdot \alpha^2}} \quad \text{(18)}$$

The Moiré patterns of specimens become complicated by lattice imperfections, such as dislocation.



(a) Double diffraction (b) Parallel pattern (c) Rotation pattern

Fig. 1.16 Formation of Moiré patterns by double diffraction

1.2.1f Electron diffraction

Like X-rays, electron beams are reflected (diffracted) at the net plane of a crystal lattice, a factor which can be utilized in the study of crystal structures. There is a close relation between electron diffraction patterns and electron microscope images. That is to say, electrons scattered by a specimen provide Fraunhofer diffraction patterns at the back focal plane of the electron lens which are in turn Fourier-transformed so as to form electron microscope images. Accordingly, the structure of the specimen can be examined by correlating the diffraction patterns and the microscope images.

However, since there are a number of differences between electrons (charged particles) and X-rays (electromagnetic waves), they cannot be treated in the same way. The wavelength of an electron, for example, is very much shorter than that of an X-ray; approximately 1/40 in fact. That is to say, the wavelength of a 100 keV electron beam is 0.0037 nm, while that of a characteristic X-ray of the CuKα line is about 0.154 nm. As a result, the radius ($1/\lambda$) of the Ewald reflection sphere increases to the extent that it can be assumed that part of the sphere is a plane. Accordingly, by using a reciprocal lattice, a diffraction pattern can be analyzed fairly simply. Electron beams, as mentioned above, interact with substances to a far greater extent than in the case of X-rays. In other words, the scattering power (diffraction wave amplitude/incident wave amplitude) of electron beams is far greater (10^6 times or more) than that of X-rays. As a result, small specimens are able to yield clear diffraction patterns. That is to say, film with a thickness of 50nm or less, crystallites, gases, etc. can be effectively studied by electron beam diffraction. However, when the crystal thickness is increased, dynamical effects cannot be disregarded in the case of electron diffraction. Generally, the identification of a substance in an electron diffraction pattern is accomplished by comparing said substance with the available X-ray diffraction data. Furthermore, electron diffraction is used to estimate the orientation of a crystal and the size and shape of a crystallite from the shape and structure of the pattern. Another factor is that since electrons are charged particles, their paths can be easily altered by the effect of magnetic or electrostatic fields. Consequently, a variety of diffraction methods for the selection of high resolution, selected area and high dispersion are possible.

When incident electron waves are scattered by atoms in a substance, the waves expand spherically from the center of the atom. Moreover, when the specimen is in a crystalline state, having a regular three-dimensional arrangement of atoms, a constant phase relationship exists between the waves emitted from the respective atoms. These waves travel in one direction only and are mutually coherent (coherent elastic scattering). This is known as the "Bragg reflection". As shown in Fig. 1.17a, waves are reflected by the atomic net planes. If the path difference, $2d \sin \theta$, (shown by the thick lines in the figure) is equal to $n\lambda$ (where n is an integer, and λ is the wavelength), the waves reflected at successive planes will be in phase. Thus, Equation (14), $2d \sin \theta = n\lambda$, is obtained.

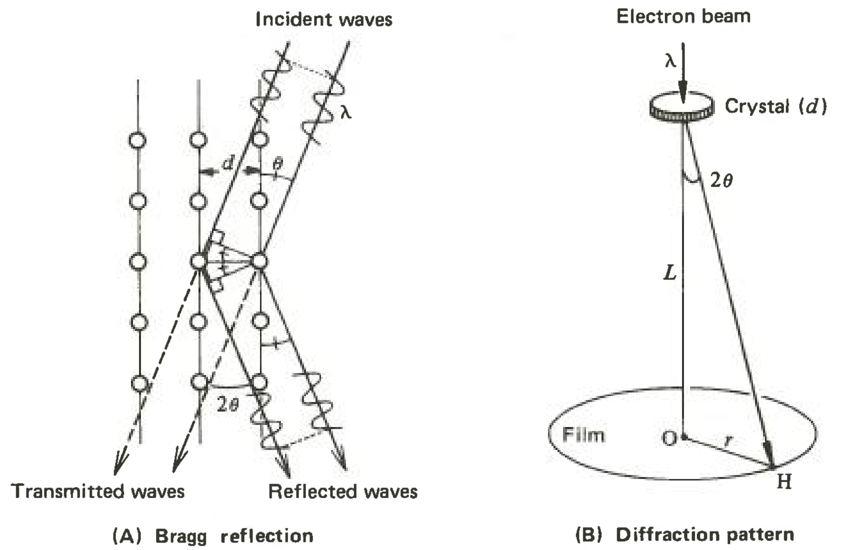


Fig. 1.17 Electron diffraction

When an electron microscope is used as an electron diffraction apparatus, the equation, $n = 1$, is changed as follows, since the Bragg angle for high-velocity electron beams is very small ($\sin\theta \fallingdotseq \theta$).

$$d2\theta = \lambda \quad (19)$$

In Fig. 1.17b, O is the center spot, H is the diffraction spot (or a point on the ring), and L is the distance between the crystal and the film (camera length). Thus, r, the distance between O and H, can be expressed as follows:

$$r = L2\theta \quad (20)$$

From Equations (19) and (20),

$$rd = L\lambda \quad (21)$$

In the above equation, if r is known and $L\lambda$ is obtained by using a known standard specimen, the unknown specimen (d) can be determined by using the same test conditions. When a thick single crystal specimen is observed by transmission electron diffraction, or when a single crystal specimen is observed by reflection electron diffraction, a band pattern (Kikuchi pattern) made up of pairs of white and black parallel lines, appears. This pattern is generated by the diffraction of the wave which has already been inelastically scattered in the crystal. By using this method, the interplanar spacing can be obtained.

Electron diffraction of a specimen micro-area can be executed by using a lens system of two or more stages. Fig. 1.18 shows the principle of selected area electron diffraction. In the figure, parallel electron beams impinge on specimens S_1 and S_2 and diffracted waves from the specimens produce diffraction patterns

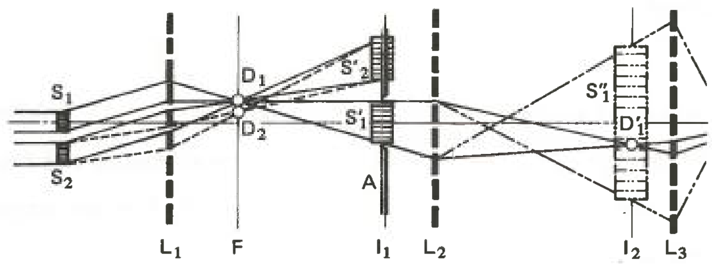


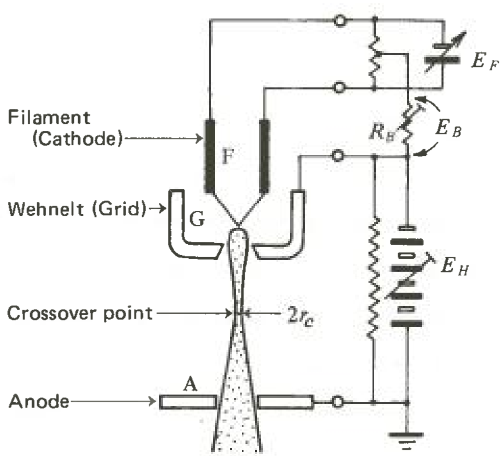
Fig. 1.18 Selected area electron diffraction

D_1 and D_2 at the back focal plane F of the objective lens L_1 so as to form magnified images S'_1 and S'_2 on the image plane I_1. When aperture A is inserted into the image plane I_1, in order to limit the field of view to the size of S'_1, only the electron beams passing through aperture A, i.e., the electrons from specimen S_1, are used to form the next stage image or diffraction pattern. When F or I_1 is brought into focus by the next stage lens, L_2, the diffraction pattern D'_1 or the magnified image S''_1 is formed on image plane I_2. The third lens L_3 produces the final image. The camera length is fixed in the case of a two image-forming lens system, but is variable in the case of a three or more-stage system. Equation (21) applies to both systems. When using the electron diffraction method, errors may result from defocusing and spherical aberration. To minimize such errors, exact focusing must be achieved or the micro-beam diffraction method must be used instead of the aperture, thereby limiting the field. Furthermore, when correlating the diffraction pattern with the image, it is necessary to take the magnetic rotation of the imaging lenses into consideration. A needle-like crystal having a known crystal structure is convenient for this purpose.

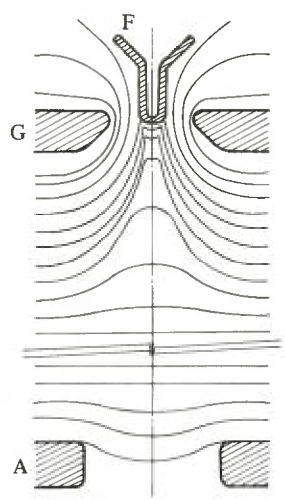
1.2.2 Outline of structure

1.2.2a Electron gun

The illuminating (electron) source of an electron microscope must meet the following requirements: high brightness, small size, and high stability, including emitted electron velocity stability. There are several types of electron gun which meet these requirements. However, generally they are composed of 3 electrodes and thermionically activated as shown in Fig. 1.19a.



(a) Structure of electron gun



(b) Equipotential surfaces

Fig. 1.19 Generation of electron beam

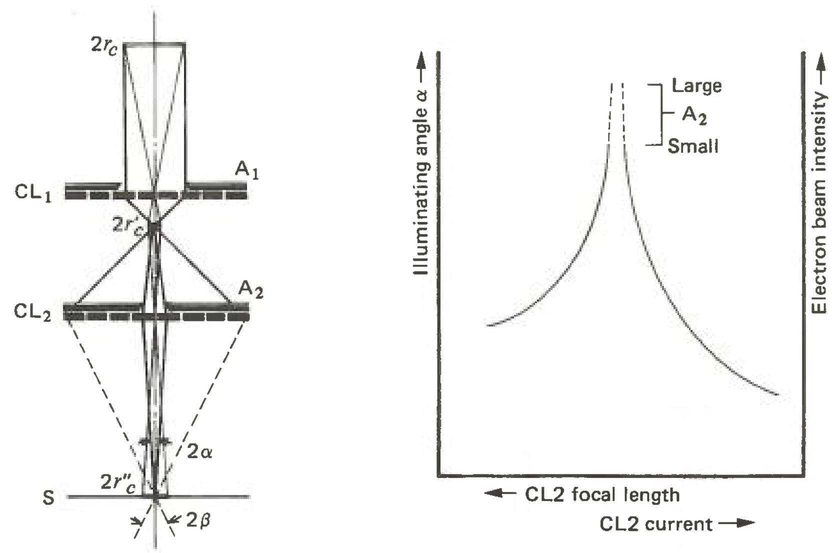
In the figure, the hot cathode F is usually a hairpin filament, but a point filament can also be used. A tungsten filament is usually employed owing to its suitable work function, high melting point, low vapor pressure, and high mechanical strength. However, a special type electron gun using LaB_6 and a field emission gun can also be used. The electrode G corresponds to the grid in a vacuum tube and is called a Wehnelt. The electrode A is an anode or plate. The characteristics of the source are determined by the shape and position of F, G and A, and the relation between their electric potentials. The JEM electron microscope uses a cool beam gun which satisfies the above-mentioned requirements.

When a negative high electric potential from the accelerating power source, E_H, is applied to the filament and a current from the heating power source, E_F, flows through the filament, thermionic electrons are emitted from the filament tip and its neighboring parts. The electrons are accelerated by the electric potential difference between the filament and anode. At the same time, a voltage drop by the bias resistance, R_B,

supplies a bias potential (self-bias) for the Wehnelt. In this case, the potential distribution between the respective electrodes, i.e., the equipotential surface, forms a kind of electrostatic cathode lens as shown in Fig. 1.19b. The electrons are concentrated to a point and emitted from that point. This electron converging point is called the "crossover point", and the minimum size of the point $2r_c$ is taken as the size of the source. The cool beam electron gun is designed to minimize the diameter of the crossover and to obtain high brightness, but with this type of gun, the filament position must be adjusted precisely; otherwise, performance will be adversely affected. The stability of the source is primarily achieved by negative feedback, using the self-bias method, but the stabilization of the power supply and countermeasures for micro-discharges must also be taken into account. When the filament is heated gradually, the quantity of the emitted electrons reaches its limit (saturation) in accordance with the space charge. The saturation point must be reached to provide the most stable source, but heating in excess of the saturation point will result in a shortening of filament service life.

1.2.2b Condenser lens

A condenser lens is required to converge the electrons emitted from the electron gun and to illuminate the specimen as desired. Since the field of view in high magnification microscopy is limited to a very small area (approx. $1\mu m^2$ at 100,000X), the illumination area must be small. If a wide area is illuminated, adverse effects will result; e.g., the specimen temperature will increase. To obtain a small illumination area, a double



(a) Double condenser lens **(b) Relation between focal length and illuminating angle**

Fig. 1.20 Electron beam illumination

condenser lens is necessary.

Fig. 1.20a shows the function of a two-stage condenser lens. In the figure, the size of the electron source $2r_c$ at the crossover point is converged to $2r_c'$ by the first stage condenser lens CL1 and the source is focused on the specimen plane S by the second stage condenser lens CL2 as shown by the source image $2r_c''$. A_1 and A_2 are apertures. The illuminating angle α near the axis is determined according to the diameter of A_2, i.e., the range designated by the broken lines (see Fig. 1.20b) is determined by A_2, and the maximum illuminating angle in this range is equal to the divergence angle β. If the source image $2r_c''$ is formed under or over the specimen plane S by changing the focal length of the second condenser lens CL2, the illuminating angle α will be reduced but the illuminated area will increase and the electron beam intensity will decrease, thereby resulting in a darker image.

The parallelism of the electron beam is perfect when $\alpha = 0$, but an allowable range of α is provided for in the design of the aperture. Except in special cases, the focus is formed near the specimen plane to illuminate the specimen evenly. Shortening the focal length of CL1 makes the source image smaller, thus narrowing the illumination area.

Furthermore, the JEM electron microscope contains an interlocking two-stage beam deflector immediately under the condenser lens. This deflector provides for illumination of the tilted beam on the specimen in order to obtain a high resolution dark field image.

1.2.2c Specimen chamber

The specimen chamber of an electron microscope must satisfy the following requirements.

(1): The specimen chamber must contain a stage capable of quick and easy specimen exchange. The stage must hold the specimen or specimen holder firmly and must move smoothly when selecting the field of view. Two types of stage are available for the JEM's: a top-entry stage and a side-entry stage. Either type is equipped as standard. In high performance electron microscopes, external vibration, which adversely affects the resolving power, must be removed. The micro-field of view at high magnification must be selected correctly and a mechanism for the quick exchange of specimens is required to increase specimen throughput. Since the specimen exchange device of JEM electron microscopes contains an airlock mechanism, the specimen can be exchanged without breaking the column vacuum.

(2): The specimen chamber must be capable of accommodating many attachments in order to widen the application scope of the microscope. Moreover, to reduce specimen contamination and maintain a high vacuum, a cooling trap must be installed near the specimen. Also, untoward beam deflection must be almost completely removed.

1.2.2d Image forming lens system

The image forming system is normally composed of three lenses: an objective lens (OBJ), an intermediate lens (INT), and a projector lens (PROJ). In a high magnification lens system, a first-stage image is formed by the objective lens (of small aberration) located immediately below the specimen. The image is further enlarged by the intermediate lens, and the final image is formed on a fluorescent screen or film by the high-magnification projector lens.

Focusing is achieved by adjusting the objective lens excitation current. Because specimens are very thin and the aperture angle is very small, the thickness of a specimen is covered by the depth of field. Owing to high magnification, the depth of focus is quite large. If the image is correctly formed on the screen, the same focus image can be obtained regardless of the film position, except in extreme cases.

An aperture inserted near the back focal plane of the objective lens has two important functions: (1) to limit the electron beam aperture angle in order to minimize aberration, and (2) to remove scattered electrons and thereby enhance image contrast. Accordingly, the selection of the aperture diameter depends on the required resolving power and contrast. In the JEM electron microscope, only suitably-sized apertures are used.

Magnification is usually changed by the intermediate lens. However, in some cases, it is changed by changing the projector lens. Fig. 1.21 shows ray diagrams for various lens combinations of a JEM electron microscope. In the figure, (a) to (f) indicate the difference in the use of lenses at various magnification ranges, (g) to (i) illustrate the use of lenses for high resolution electron diffraction, selected area electron diffraction and high dispersion electron diffraction.

In an electron microscope system, the optical axes of the lenses must be aligned with each other and misalignment of the axes must be rectified simply and quickly. The JEM electron microscope is designed to meet these requirements.

1.2.2e Viewing chamber and camera chamber

Since images formed by the electron beam cannot be directly observed with the naked eye, they must be converted into light images in order to select the field of view and effect focusing. There are two conversion methods: one is by means of a fluorescent screen (metal plate containing phosphor, green or yellow, with high visibility), in which case, observation is made from the same side as the electrons travel; the other is by means of a transmission (TV) type screen, in which case the image can be observed from the opposite side. The latter is mainly used for small-sized electron microscopes. For easy observation of images on the fluorescent screen, the light emitting efficiency and resolving power of the screen must be high. All JEM electron microscopes use a fluorescent screen on which high quality phosphor is applied. For easier observa-

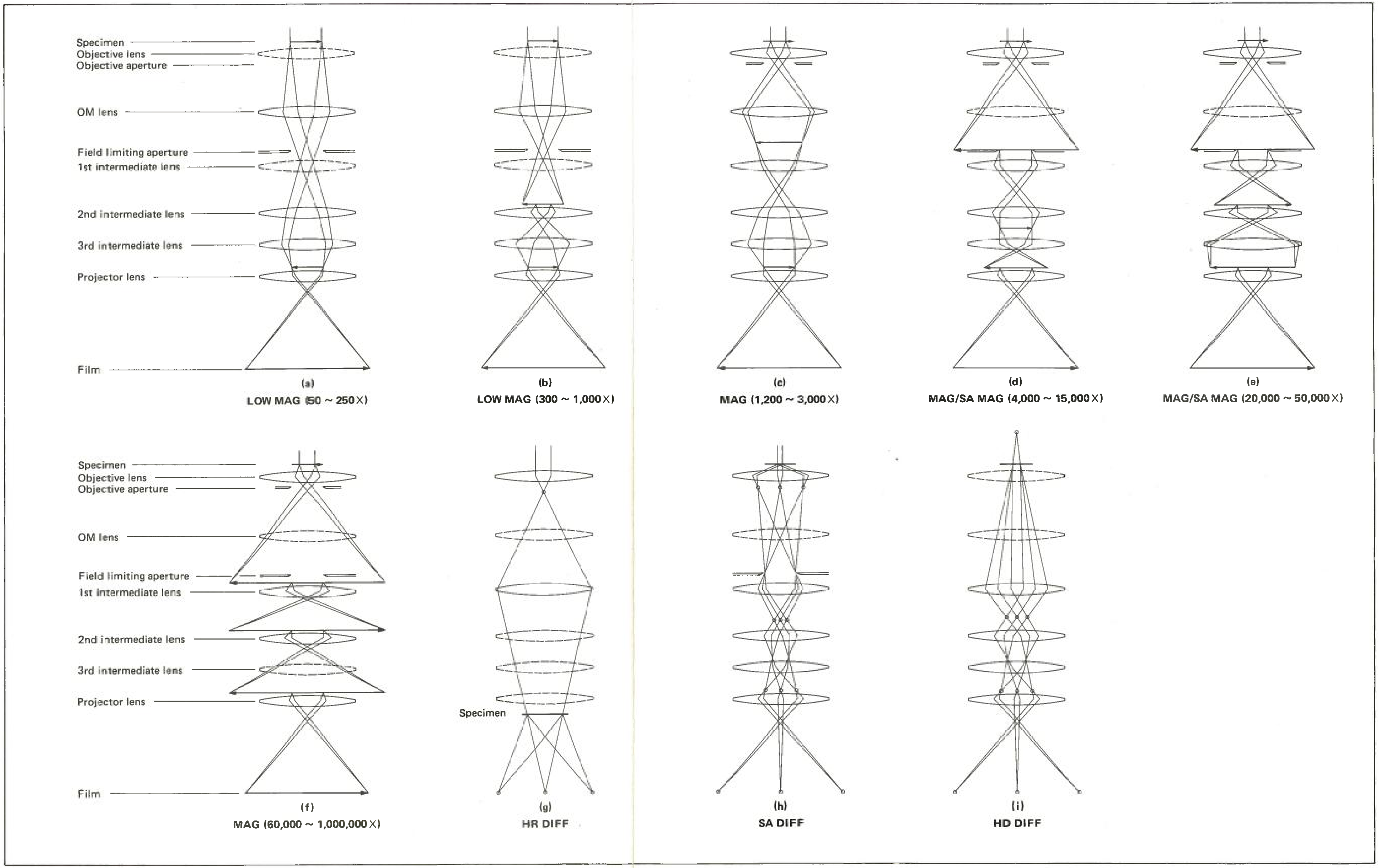


Fig. 1.21 Use of lenses and ray diagrams

tion, binoculars with a clear field of view are installed to enlarge the image fomred on the screen.

The best way to record electron microscope images is to use direct photography with high resolving power film. Each JEM electron microcope includes a fully automatic camera, complete with a data recording device, and its speically designed automatic exposure mechanism ensures optimum exposure. Since this camera is equipped with an airlock mechanism, rapid film exchange can be executed without breaking the column vacuum.

1.2.2f Vacuum system

Electrons are greatly influenced by the medium through which they pass. Accordingly, the pressure in the column must be maintained at 10^{-3} Pa or less. Analytical electron microscopes require still higher vacuum.

To achieve the required vacuum degree, electron microscopes are usually evacuated by an oil diffusion pump backed by an oil rotary pump. Nowadays, dry pumps such as sputter-ion pumps, turbomolecular pumps, etc. are used instead of the oil diffusion pump to minimize specimen contamination.

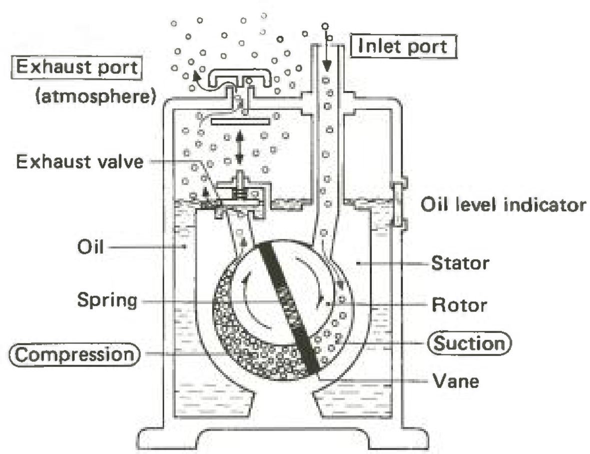


Fig. 1.22 Structure of a Gaede oil rotary pump

Fig. 1.22 shows the structure of a Gaede oil rotary pump. The pump contains oil, which serves to lubricate the pump and to make it airtight. When the rotor turns in the direction of the arrow, the gas in one chamber is compressed so that the pressure in the chamber becomes greater than atmospheric pressure, and the gas is pumped out through the exhaust valve into the atmosphere. Simultaneously, gas enters the other chamber ready for the next compression. That is to say, two pumping processes take place as the rotor rotates through one revolution.

The sputter-ion pump basically consists of an anode, a cathode and a magnet, as shown in Fig. 1.23.

When a voltage is applied between the two electrodes at a gas pressure, an electrical discharge occurs. Electrons tend to move to the anode, while positive ions travel to the cathode. The magnetic field causes the electrons to execute spiral paths and before they reach the anode, they collide with gas molecules and ionize them, producing gas ions and electrons, and electrons newly produced further cause gas molecule ionization, thereby an avalanche. The positive ions strike the cathode and eject Ti atoms. The ejected Ti atoms deposit on the anode cells and Ti layers are continuously produced. A newly created Ti layer has a very active getter action and active gasses are finally adsorbed on the anode in the form of a Ti compound, while inert gasses are buried in the newly created Ti layers and the places on the cathode where the ejection of Ti atoms is not very active.

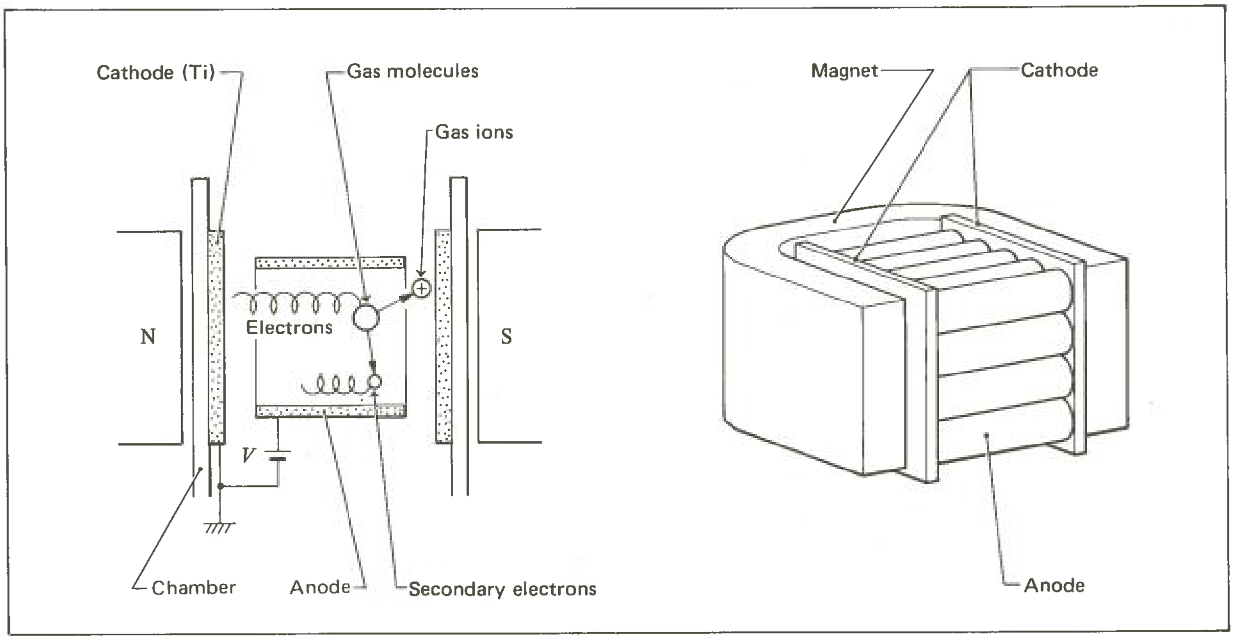


Fig. 1.23 Sputter-ion pump

To operate the ion-sputter pump, the column has to be evacuated in advance to a given vacuum degree using a turbomolecular pump, etc. The turbomolecular pump consists of a high speed rotor and a stator fixed in the housing. The rotor and stator blades are provided with a large number of slots and arranged in the opposite way to each other as shown in Fig. 1.24. When gas molecules impinge on the rotor blades, gas molecules acquire momentum in the direction of the moving blades. In the molecular flow range, since the mean free path of the gas molecules is greater than the spacing of the blades, the appropriate configuration of rotor and stator blades ensures that the transmission velocity of molecules from the high vacuum side toward the forevacuum side is considerably greater than in the opposite direction.

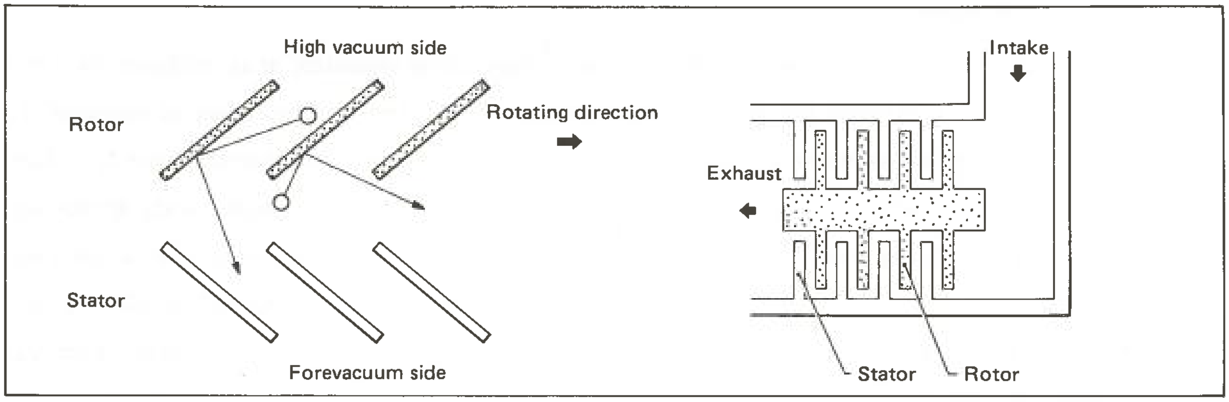


Fig. 1.24 Turbomolecular pump

The column is roughed by the oil rotary pump, then evacuated by the turbomolecular pump and finally by the sputter-ion pump. The vacuum status can be monitored by Pirani and Penning gauges during the evacuation. Fig. 1.25 shows a schematic diagram of a typical vacuum system. In the electron microscope, minimizing outgassing is another key factor to improving the specimen environment. To comply with this requirement, deflector coils, stigmator coils as well as lens coils in advanced instruments are placed outside vacuum; metallic bellows are used in many movable parts instead of rubber and elastomer O-rings; further, a bake-out facility is built-in for column degassing; the camera and viewing chambers are differentially pumped out to prevent gas evolved from films from diffusing into the specimen chamber.

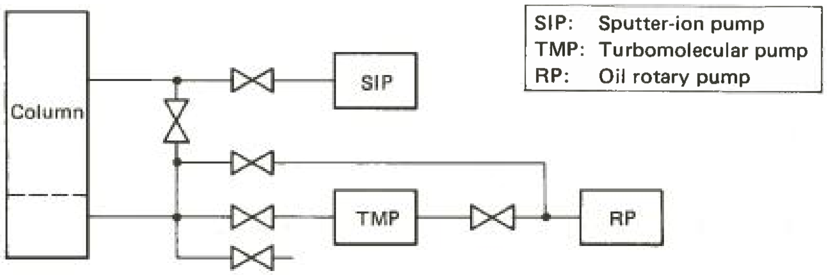


Fig. 1.25 Schematic diagram of vacuum system

1.2.2g Electrical system

Fig. 1.26 shows the schematic diagram of a high voltage circuit consisting of an oscillator, switching transistors, a stepup transformer and a high voltage rectifier. This circuit operates when an oscillator frequency is the same as the resonance frequency f_o depending on the stepup transformer reactance L_o and the stray capacity C_o (as viewed from the secondary terminal of stepup transformer against a load). In this case, the output voltage of stepup transformer e_o is linear to the input voltage V_{in}, the waveform of e_o is sine wave, while transistors TR1 and TR2 operate with a phase difference of 180° (modified push-pull amplifier circuit). The voltage e_o is supplied to the high voltage rectifier and the DC output voltage $-E_{HV}$ is a negative high voltage six times the peak of e_o at the last stage.

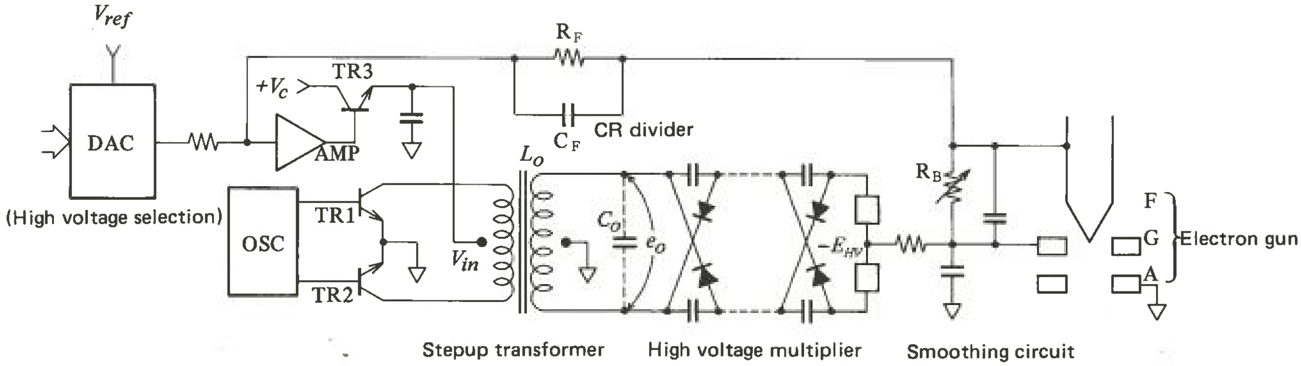


Fig. 1.26 Schematic diagram of high voltage circuit

A balanced type Cockcroft-Walton circuit is used as a high voltage rectifier for multiplication and rectification. The merit of using this circuit is that the capacity of the smoother condenser can be small since ripple components in this case are smaller compared with other circuits, thus resulting in a smaller capacity of the high voltage generator. The output voltage is stabilized by negative feedback of the error voltage introduced to the error amplifier AMP via the CR divider to control the base voltage of TR3. The high voltage is selected by changing the input voltage of DAC and the beam current is changed by adjusting the bias resistor R_B.

The basic lens excitation current circuit is shown in Fig. 1.27. The lens current is stabilized by negative feedback of variation of the lens current to the error amplifier via the resistor R_F, comparing the resultant voltage with the DAC output voltage and controlling the AMP output. The lens current can be easily controlled by changing the input data of DAC by the computer-controlled circuit.

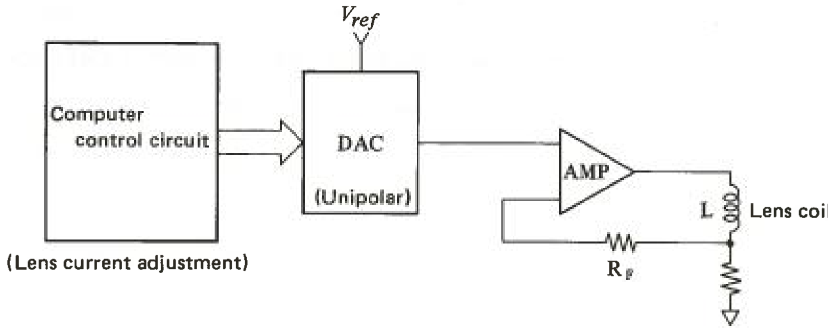


Fig. 1.27 Schematic diagram of lens circuit

Fig. 1.28 shows the basic circuit for the beam deflector excitation current. The fundamental construction is almost the same as that for the lens circuit. To set the current, two methods are used; one changes the DAC input data by the computer-controlled circuit (a) and the other adjusts the variable resistor RV (b).

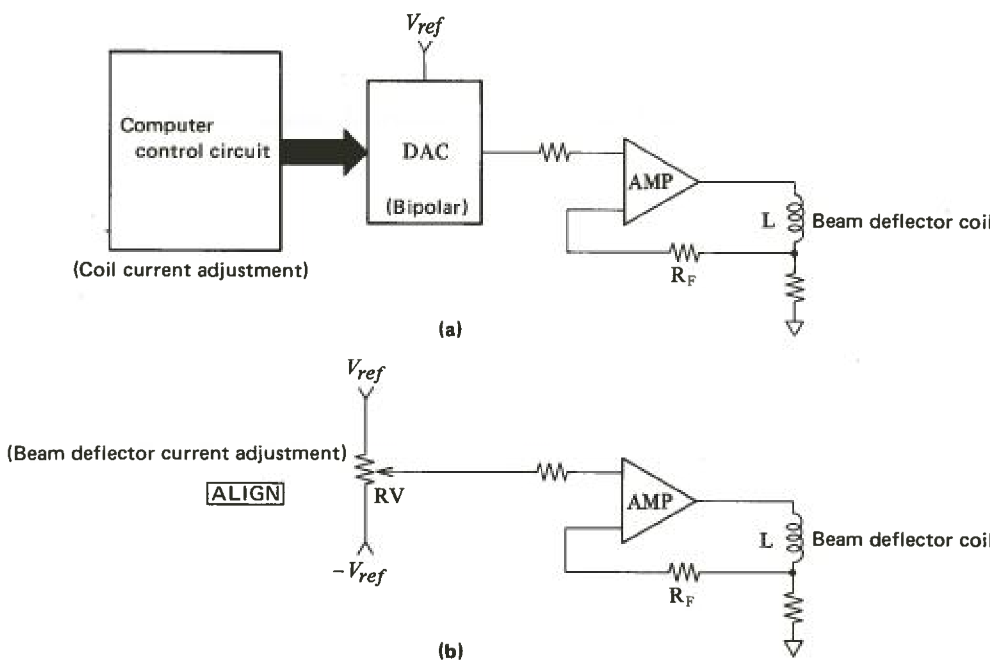


Fig. 1.28 Schematic diagram of beam deflector circuit

Fig. 1.29 shows the exposure circuit. The electron beam, passing through the specimen and impinging on the fluorescent screen, is supplied to the preamplifier AMP1 or AMP2 (AMP1 operates when the small screen is in the beam path and AMP2 when the small screen is out), after being converted into a voltage, fed to the main amplifier, and then converted into a digital signal by the ADC. Finally, the correct exposure time is calculated by the CPU.

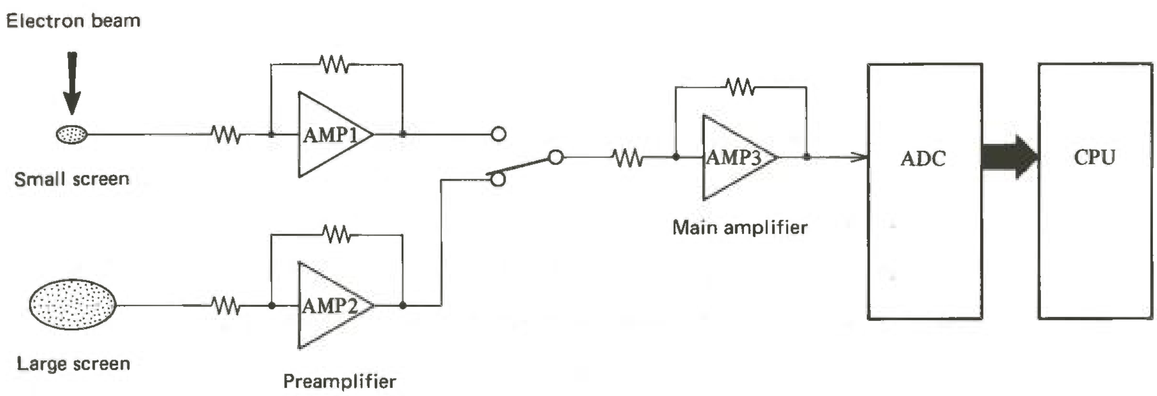


Fig. 1.29 Schematic diagram of exposure circuit

2. SPECIFICATIONS

2. SPECIFICATIONS

This chapter covers the specifications relative to setting up and operating the microscope when the SHP high resolution pole piece is used.

2.1 Performance

- Guaranteed resolution: 0.14 nm (lattice).
  0.3 nm (point to point).
- Accelerating voltage: 40, 60, 80, 100, 120 kV.
- Magnification (digital display, film printout)
  - Standard magnification mode: 1,200× to 1,000,000× in 30 steps.
  - Selected area magnification mode: 4,000× to 500,000× in 22 steps.
  - Low magnification mode (LOW MAG): 50× to 1,000× in 14 steps.
- Electron diffraction camera length (digital display, film printout)
  - Selected area electron diffraction: 100 to 2,500 mm in 15 steps.
  - High dispersion diffraction: 4 to 80 m in 14 steps.
  - High resolution diffraction: 337 mm (EM-AD high resolution diffraction stage: optional).

2.2 Electron optical system

2.2.1 Illuminating system

- Electron gun (cool beam type)
  - Filament: Precentered hairpin type tungsten filament, DC heating.
  - Bias: Self-bias, continuously variable.
  - Alignment: Electromagnetic 2-stage interlocking system.
  - Anode chamber airlock mechanism and electron gun lift: Built-in, pneumatic control.
- Condenser lens (electromagnetic, double condenser type)
  - Aperture: 200, 300, 400 μm in diameter (click-stop changeover).
  - Stigmator: Electromagnetic type, complete with centering device.
  - Alignment: Electromagnetic 2-stage interlocking system.
- Beam tilting angle: Max. 6° in all directions.

2.2.2 Image forming system

- Image forming lens system: Rotation-free, electromagnetic 6-stage system (objective lens, OM lens, 1st, 2nd and 3rd intermediate lenses, projector lens).
- Apertures (molybdenum film)
  - Objective lens apertures: 20, 50 and 80 μm in diameter (click-stop changeover).
  - Field limiting apertures: 20, 100 and 300 μm in diameter (click-stop changeover).
- Stigmator: Electromagnetic type, complete with centering device; two circuits each for low magnification and standard magnification.

2.3 Specimen stage

• Specimen exchange:	Airlock mechanism.
• Loading capacity:	Two specimens.
• Specimen anticontamination device:	Optional (EM-ACD10).
• Specimen movement range	
X and Y directions:	±1 mm (position of field of view under observation displayed on CRT).
Z direction:	±0.5 mm.
• Specimen tilt angle:	±25° (X tilt).

2.4 High resolution diffraction chamber

• High resolution electron diffraction stage:	Choice of three types (EM-AD, EM-AHC, EM-ACC) – option extras.

2.5 Viewing chamber

• Viewing window:	270 mm X 170 mm, 90 mm X 80 mm (2).
• Fluorescent screens:	160 mm and 20 mm in diameter.
• Binoculars (10X):	Built-in.
• Beam stopper:	Optional (EM-BS10).

2.6 Camera chamber

• Film	
Standard size:	65 mm X 90 mm.
Large size:	80.9 mm X 99.6 mm (available to order).
Loading capacity:	Up to 50.
Feeding:	Fully automatic (single film feeding also possible).
Exchange mechanism:	Airlock type.
• Exposure:	Automatic exposure (manual exposure also possible).
• Data recording:	Film number, magnification/camera length, accelerating voltage, micron bar and calibrated length, and characters (keyboard entry).

2.7 Vacuum system

• Vacuum pumps:	Oil rotary pump and two of turbomolecular pump, shutter-ion pump and oil diffusion pump.
• Ultimate pressure:	10^{-5} Pa (specimen chamber).
• Vacuum gauges:	Penning and Pirani gauges.
• Vacuum valves:	Automatically controlled pneumatic and solenoid valves.

2.8 Installation requirements

2.8.1 Power supply cooling water

- Power supply: Single phase, 200/220/240 V, 50/60 Hz, 5.5 kVA.
- Grounding terminal: 100 Ω or less, 1.
- Cooling water
  - Flow rate: 4 to 7 ℓ/min.
  - Pressure: 0.1 to 0.4 MPa.
  - Temperature: 15 to 20°C.
  - Faucet: 14 mm O.D. (for 1/2″ hose), 1.

2.8.2 Installation room

- Floor space: 2,800 mm (width) × 3,000 mm (depth) or more.
- Ceiling height: 2,500 mm or more.
- Doorway: Width: 800 mm or more.
Height: 1,800 mm or more.
- Room temperature: 20 ± 5°C.
- Humidity: Below 80%.
- Tolerable external magnetic fields: Less than 0.1 μT.
- Floor strength: Better than 3.5 kPa.
- Compressed air: 0.35 to 0.45 MPa (gauge pressure).

2.8.3 Dimensions and weight (mm and kg)

Table 2.1 Dimensions and weight

	Width	Depth	Height	Weight
Console	1,990 (78″)	2,000 (79″)	2,480* (97″)	1,150 (2,500 lbs)
Power supply	570 (22″)	700 (28″)	1,200 (47″)	180 (400 lbs)
Pump box	360 (14″)	240 (9.5″)	510 (20″)	55 (120 lbs)
Air compressor (option)	Diameter 420 (17″)		800 (32″)	45 (99 lbs)

* The height when the electron gun is hoisted.

2.9 Warranty

With the exception of damage resulting from natural disasters and careless handling, this instrument is guaranteed for a period of one year from the time of installation, and any and all faults or failures occurring during this period will be repaired free of charge at the installation site.

Note: These specifications are subject to change without notice.

3. COMPOSITION AND CONSTRUCTION

3. COMPOSITION AND CONSTRUCTION

3.1 Composition

The composition of this microscope is shown in Fig. 3.1-1. For detailed dimensions, refer to Sect. 2.8.

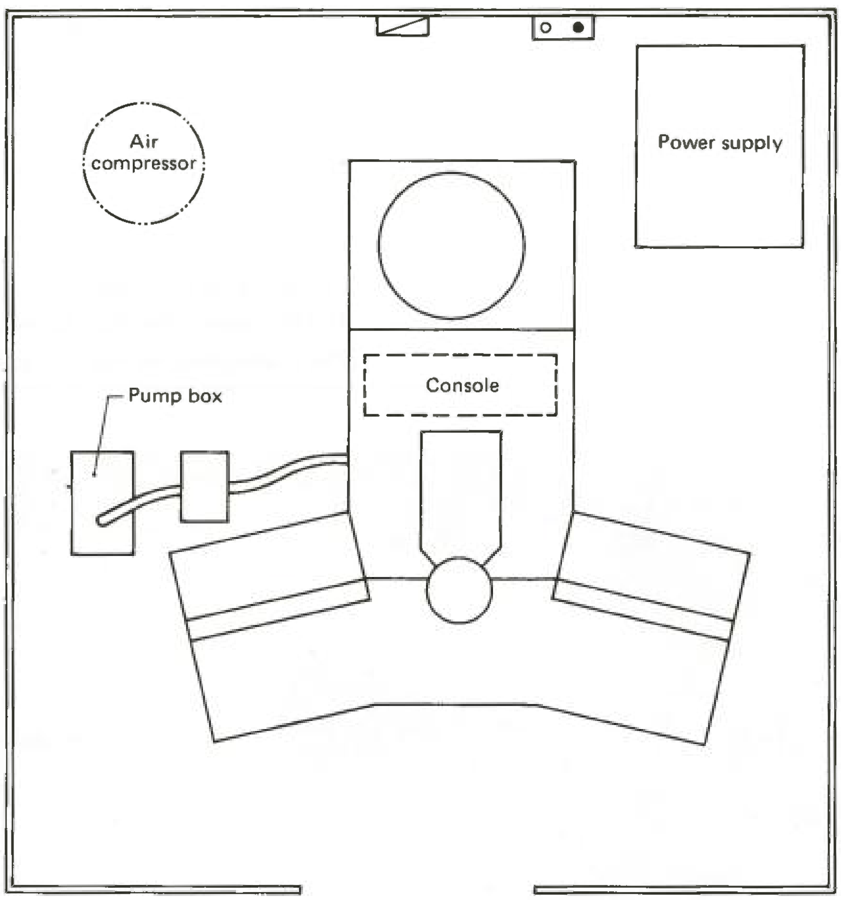


Fig. 3.1-1 Composition and layout diagram

3.2 Accessories

The standard accessories for this microscope are listed below. However, this list (especially the quantity) is subject to change. Although some of the items are not used by the users, they should nevertheless be carefully stored as they will be required for servicing purposes.

No.	Name	Quantity	Purpose
Fig. 3.2-1			
①	Boat	1	For cleaning aperture foils
②	Washers	8	For attaching the boat
③	Specimen grid case	1	(Optional)
④	Lever	1	For assembling camera chamber parts
⑤	Suction disks	2	For removing the window glass
⑥	Hand blower	1	For removing dust
⑦	Tweezers	1	(Optional)
⑧	Fomblin grease		For lens system O-rings
⑨	Apiezon grease		For O-rings in other than lens system
⑩	Silicone grease		For coating the electron gun insulator

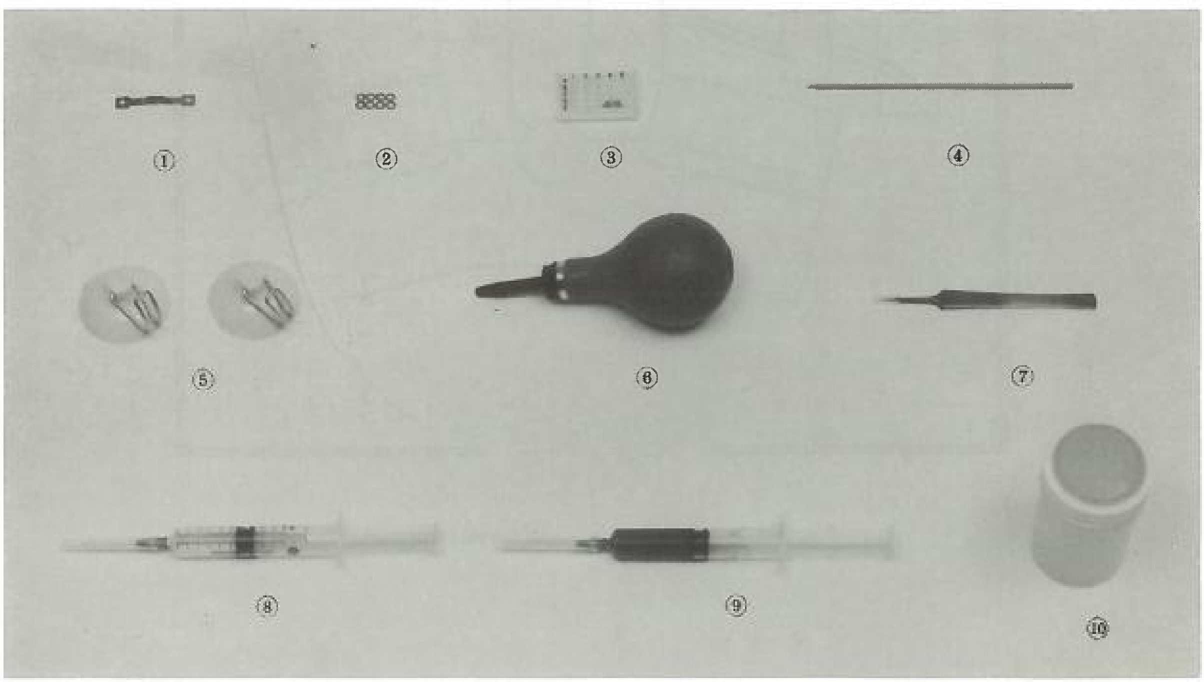


Fig. 3.2-1 Accessories (1)

No.	Name	Quantity	No.	Name	Quantity
Fig. 3.2-2					
①	Phillips screwdrivers	3	⑥	Open-end wrenches	4
②	Hexagonal head screwdrivers	3	⑦	Box-end wrenches	2
③	Standard screwdrivers	6	⑧	Adjustable wrench	1
④	Short shank screwdrivers	2	⑨	Nut driver	1
⑤	Hex keys	10	⑩	Tool bag	1

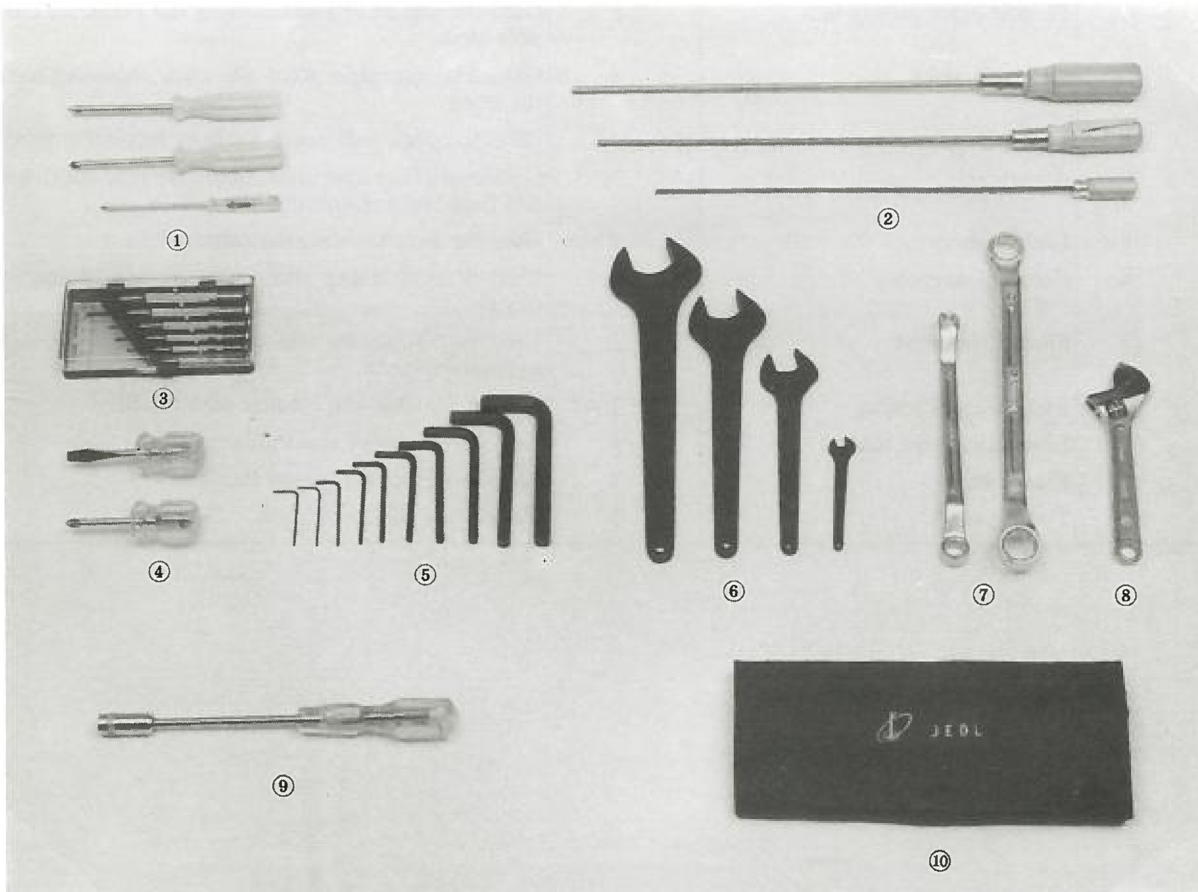


Fig. 3.2-2 Accessories (2)

No.	Name	Quantity	Purpose
Fig. 3.2-3			
①	Funnel	1	Used for pouring refrigerant into the anticontamination device
②	Refrigerant drainer	1	Used for draining refrigerant from the anticontamination device
③	Small fluorescent screen (encased)	1	Spare
④	Wehnelt adjusting tool	1 set	Used for adjusting the Wehnelt cap-filament distance
⑤	OL pole piece setting tool	1	Used for installing and removing the objective lens pole piece
⑥	PL pole piece setting tool	1	Used for installing and removing the projector lens pole piece
⑦	SAP pole piece	1	Objective lens pole piece for work requiring high tilt angle
⑧	SHP pole piece	1	Objective lens pole piece for high resolution work
⑨	Apertures	3	Condenser lens apertures, objective lens apertures and field limiting apertures
⑩	Lens tools	2	Used for disassembling the column
⑪	Compass wrench	1	Used for tightening and loosening special screws (nuts)
⑫	Special hex keys	2	Used for tightening and loosening screws located in narrow places
⑬	Flat-bars and screws	1 set	Used for linking the column with the lift
⑭	Evacuation pipe tool	1	Used for removing evacuation pipe
⑮	Flange tool	1	Used for removing special flanges
⑯	Tool box	1	For storing the above tools

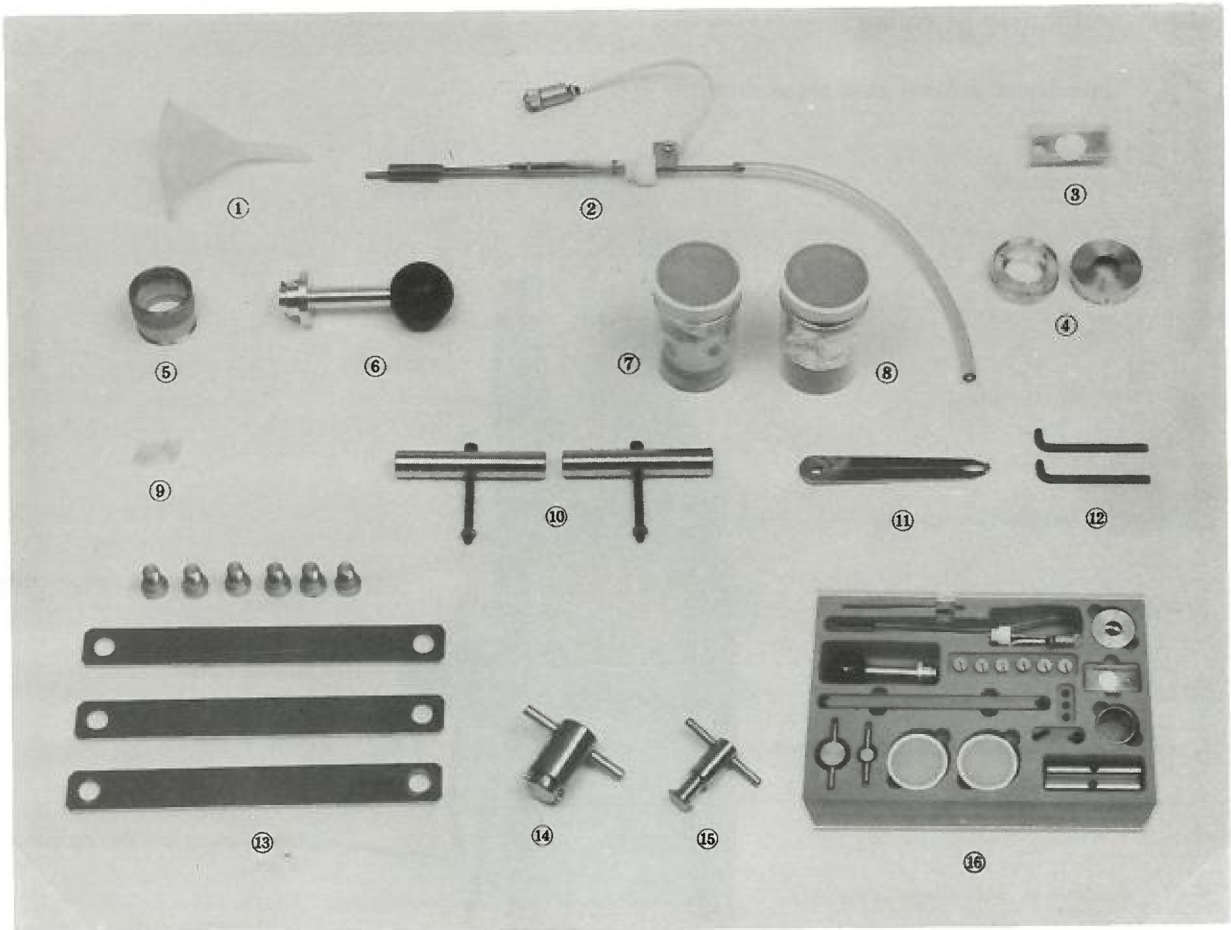
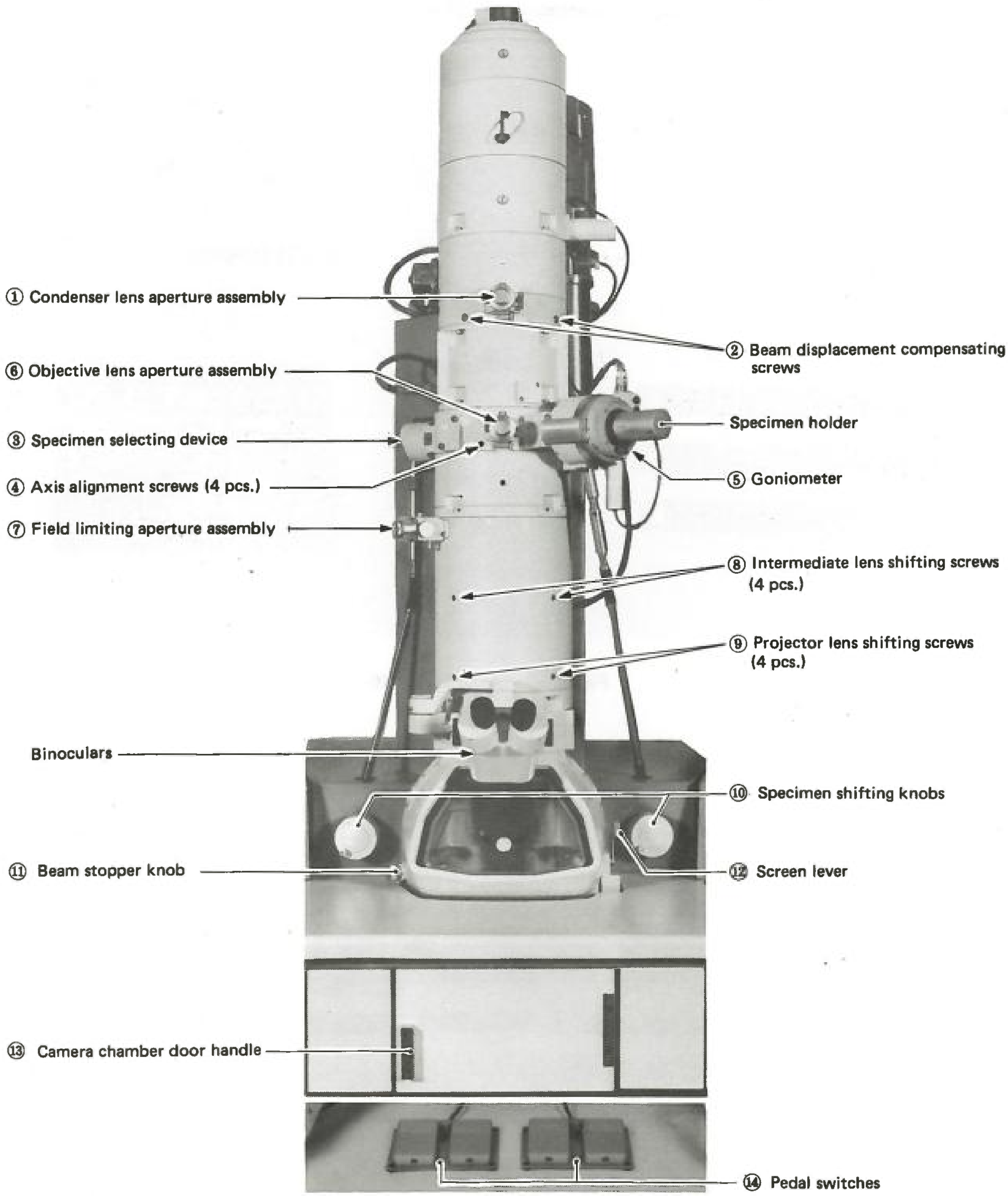


Fig. 3.2-3 Accessories (3)

3.3 Construction of column

The essential column parts are as shown in Fig. 3.3-1.



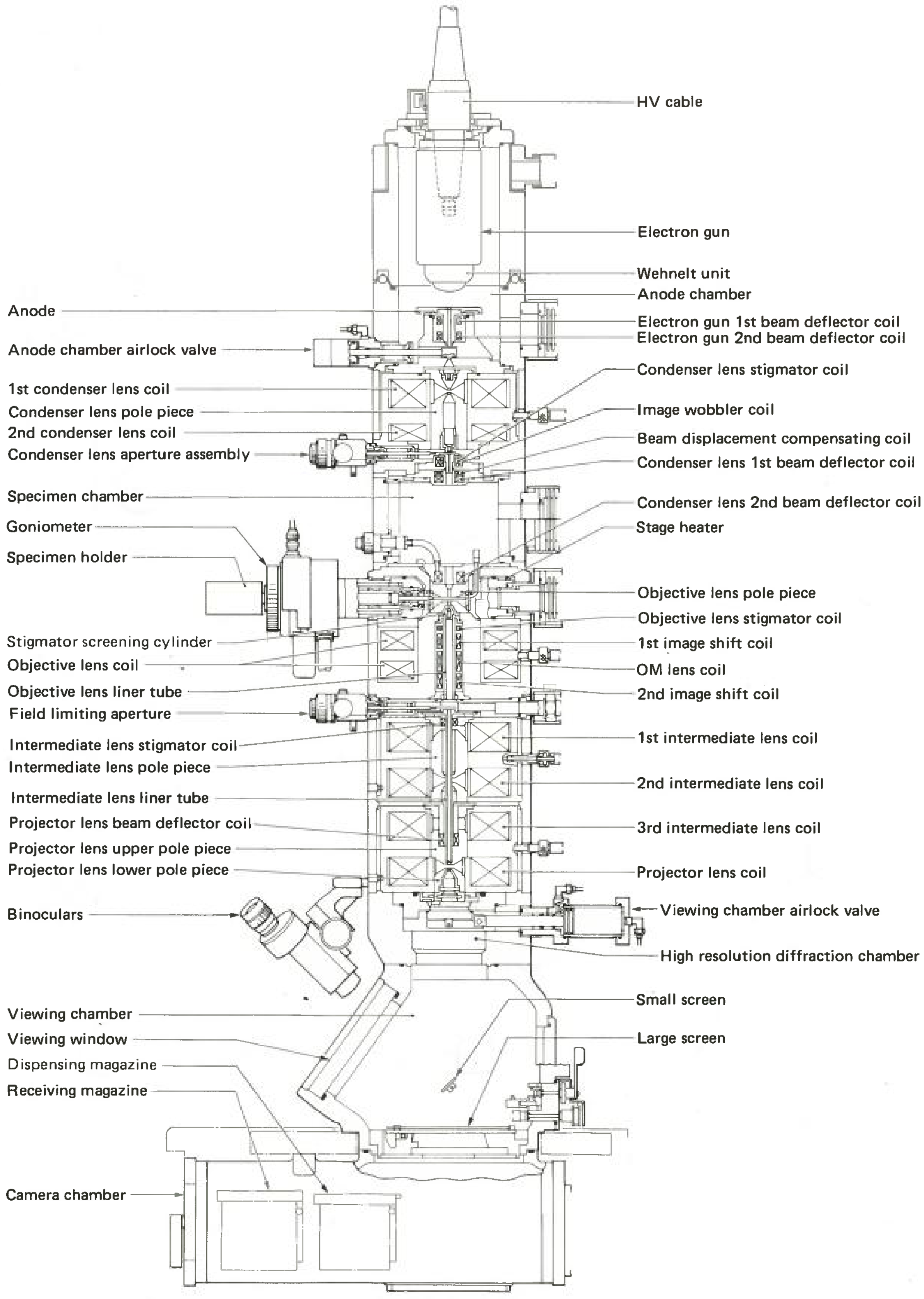
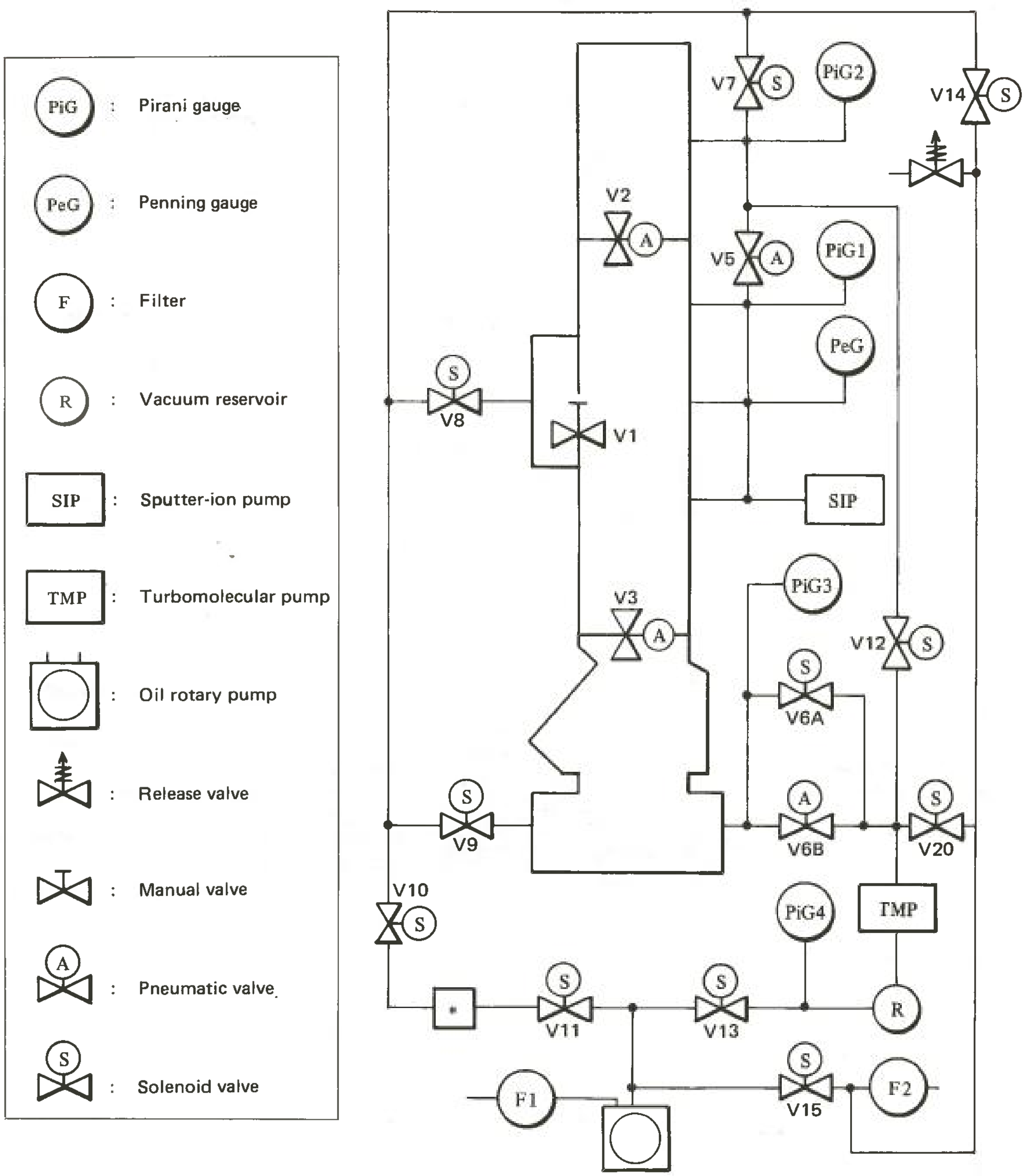


Fig. 3.3-2 Cross section of microscope column

3.4 System diagrams

The vacuum system, compressed air system, cooling water system, and electrical system are illustrated in the following schematic and block diagrams.



* This vessel is used as a trap when filled with activated alumina. For further information, please contact your local JEOL Service Center.

Fig. 3.4-1 Vacuum system

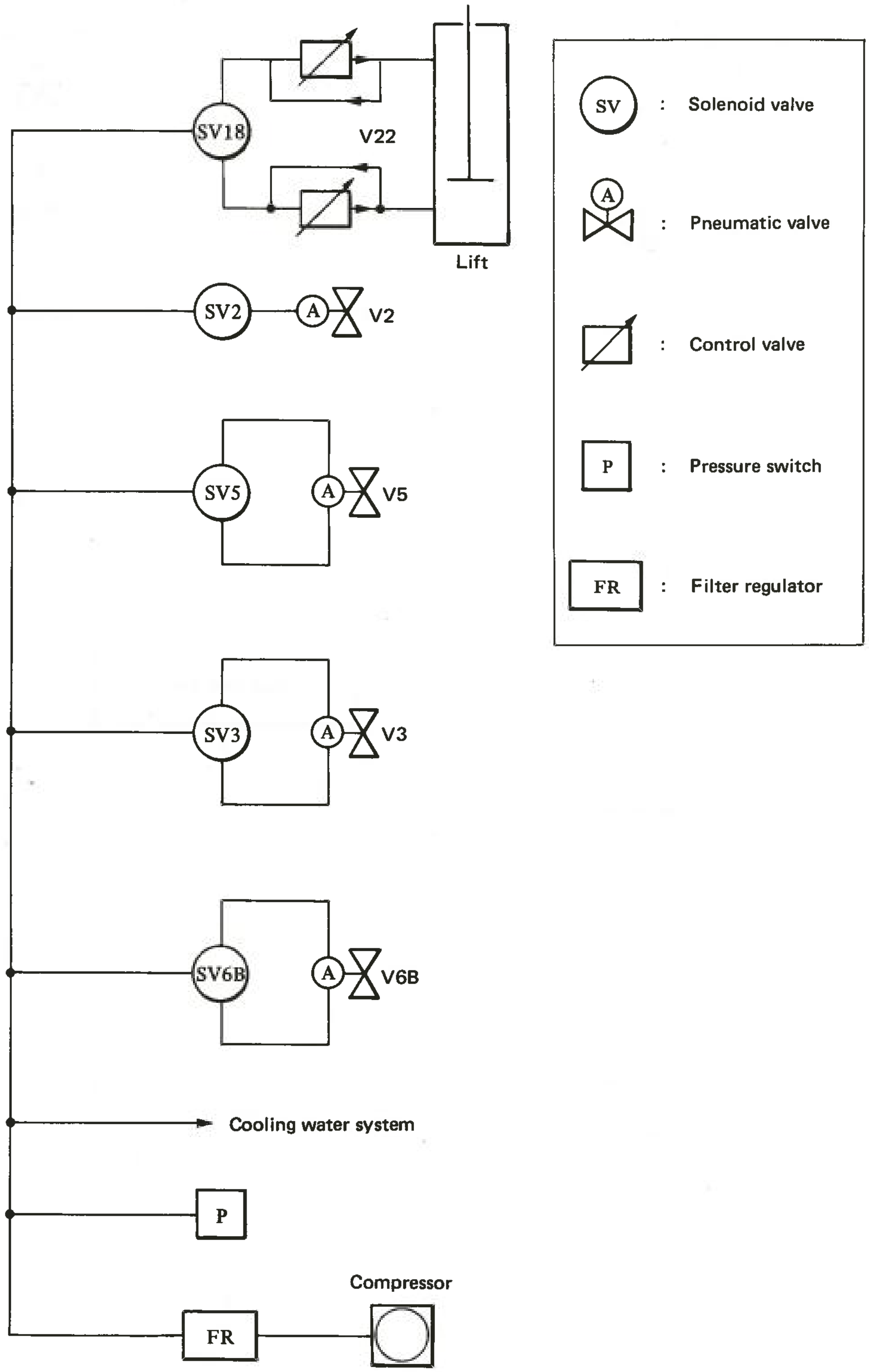


Fig. 3.4-2 Compressed air system

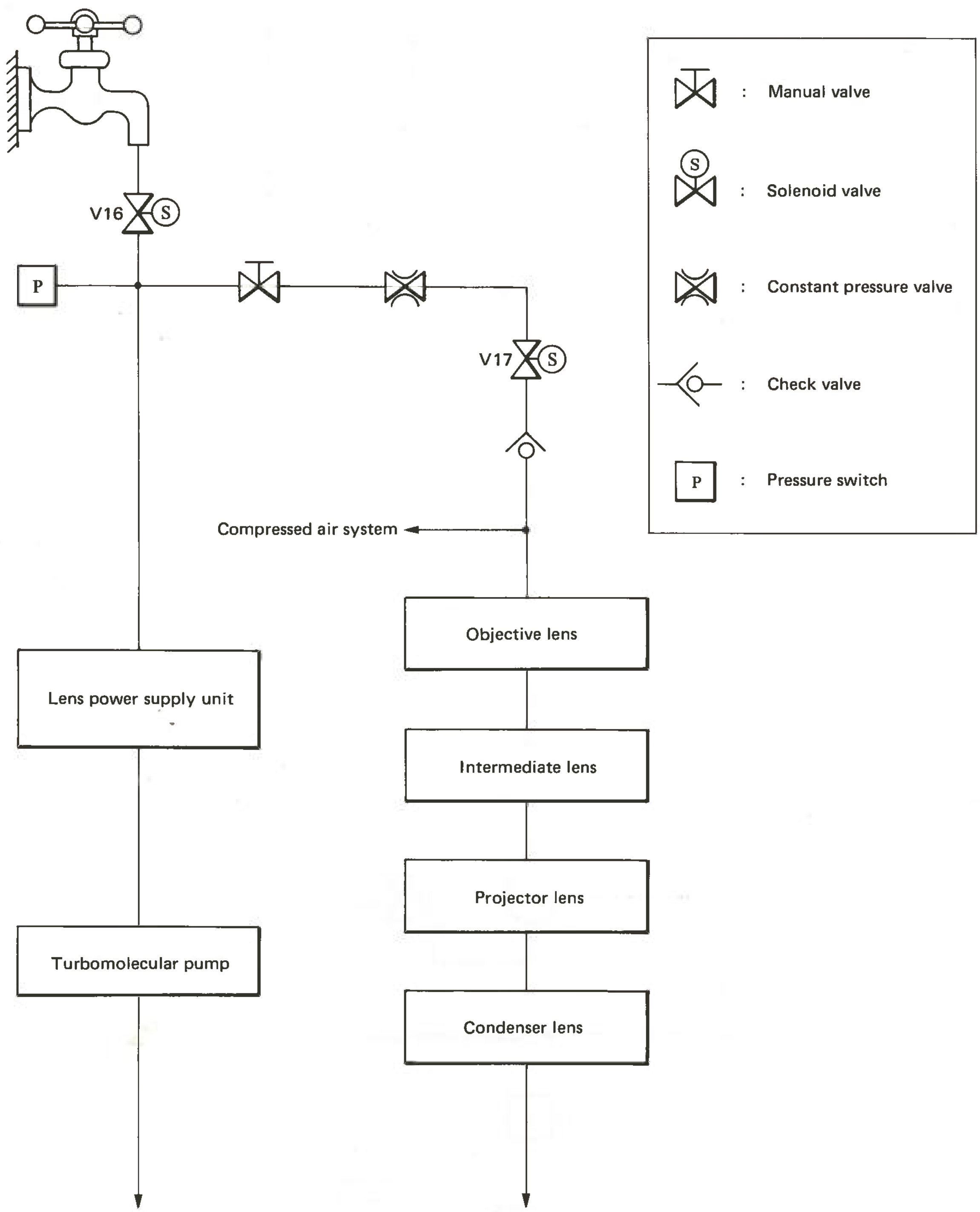


Fig. 3.4-3 Cooling water system

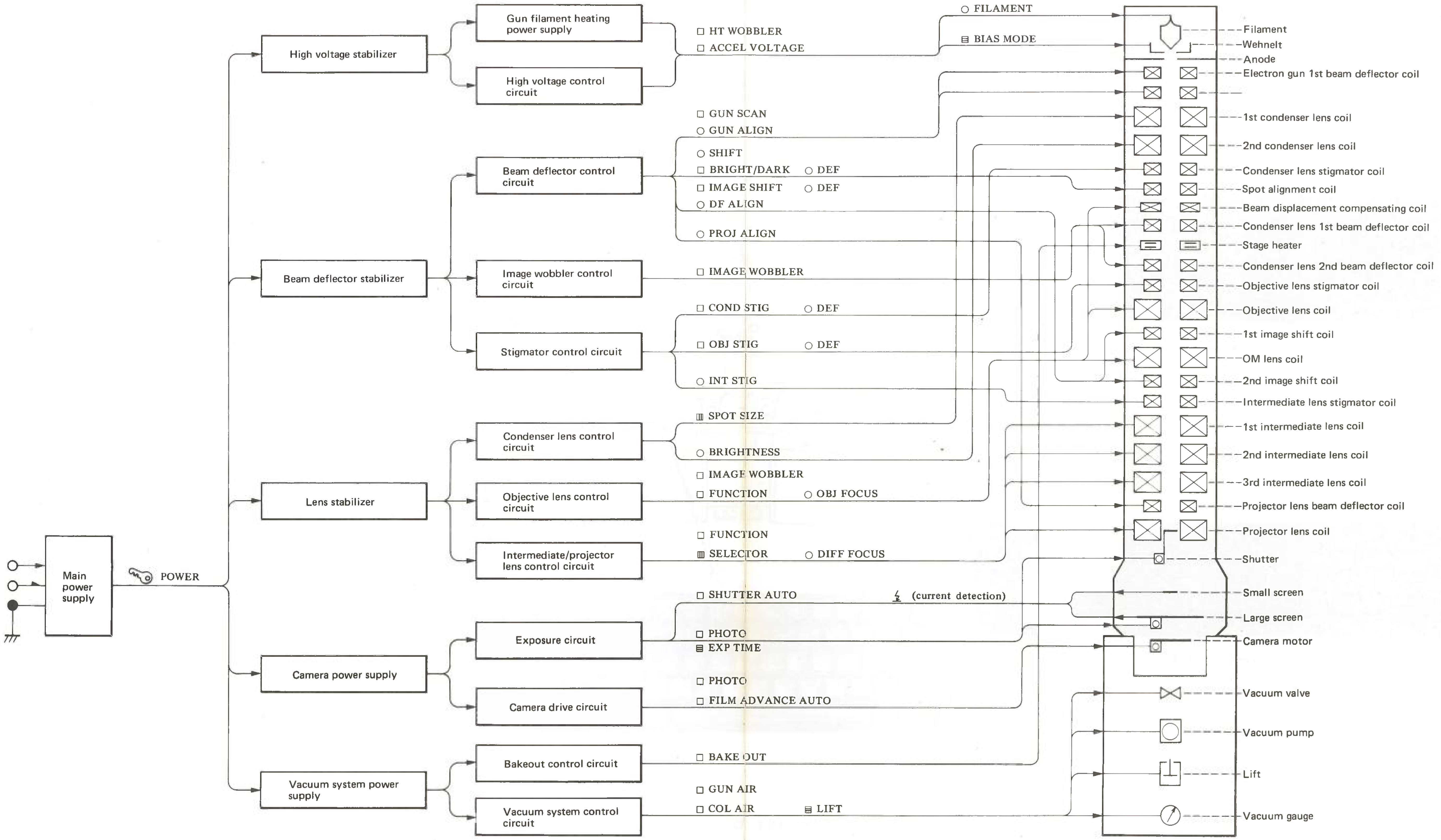
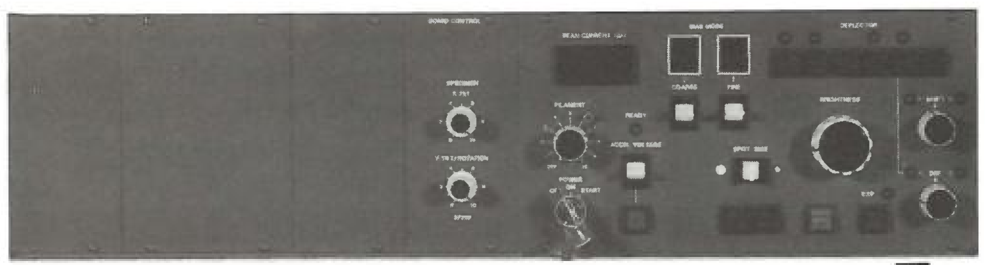


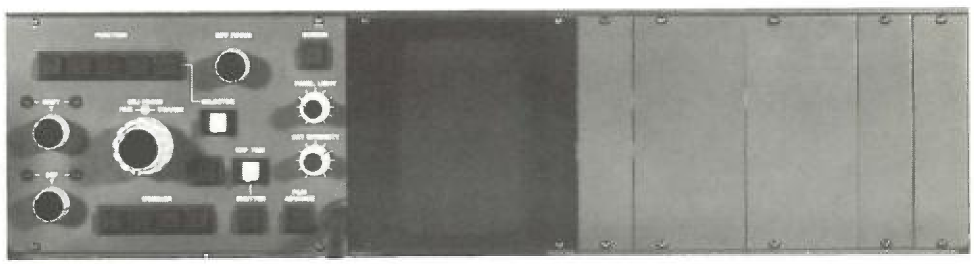
Fig. 3.4-4 Electrical system

3.5 Location of control panels

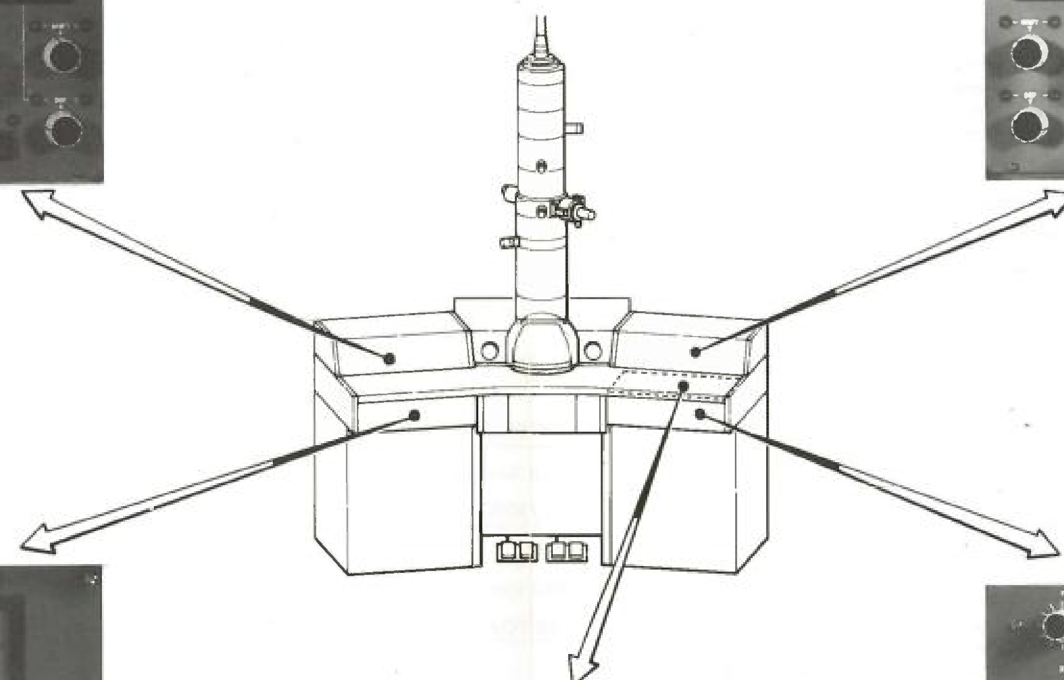
Control panels L2 and R2 are accessible by opening covers L2 and R2. Cover L2 opens when the right upper corner of the cover is tapped and cover R2 opens when the left upper corner of the cover is tapped. The key board appears when control panel R2 is drawn out.



Control panel L1



Control panel R1



Control panel L2

Control panel R2

Keyboard

Fig. 3.5-1 Control panels

4. DESCRIPTION OF COLUMN AND PANEL CONTROLS

4. DESCRIPTION OF COLUMN AND PANEL CONTROLS

4.1 Column (see Fig. 3.3-1)

No.	Name	Description
①	Condenser lens aperture assembly	(see Fig. 4.1-1)
	Knob 1	By clicking the knob, the condenser lens apertures are selected corresponding to the respective dot (•) positions. Dot position — Aperture size 6 o'clock — Large Half past 7 — Medium 9 o'clock — Small The selected aperture is positioned in the electron beam path when the lever is set left.
	Knobs 2 and 3	Used for centering the aperture by shifting it in the X and Y directions on the horizontal plane.
	Lever	By setting the lever to the left side, the aperture is positioned in the electron beam path, and by setting the lever to the right side, the aperture is retracted from the beam path.

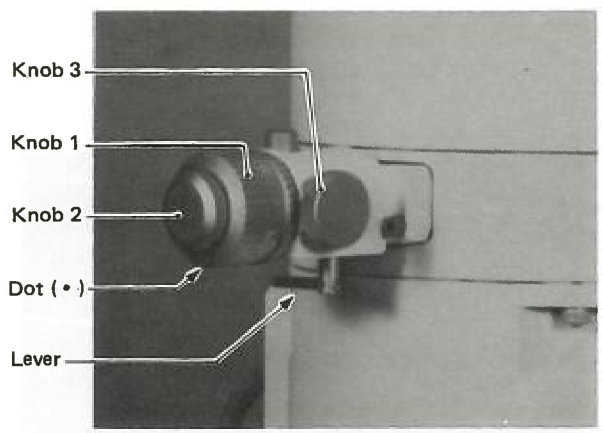


Fig. 4.1-1 Aperture assembly

②	Beam displacement compensating screws	Used for compensating for electron beam shift which results when the OBJ FOCUS knob (control panel R1) is manipulated.

No.	Name	Description
③	Specimen selecting device	(see Fig. 4.1-2)
	Specimen selector	Used for selecting either one of the two specimens mounted on the specimen holder.
	Specimen number indicator	Indicates which specimen (1 or 2) is being observed. Changeover from 1 to 2 or 2 to 1 is effected by manipulating the specimen selector. 1 and 2 on the indicator correspond to the engraved numbers 1 and 2 on the specimen holder.

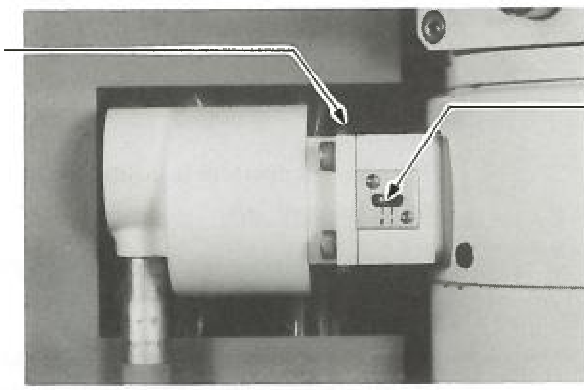


Fig. 4.1-2 Specimen selecting device

④	Axis alignment screws (4 pcs.)	Used for aligning the specimen tilt axis.
⑤	Goniometer	(see Fig. 4.1-3)
	X-tilt knob	Used for tilting the specimen around the X axis (i.e., around the axis

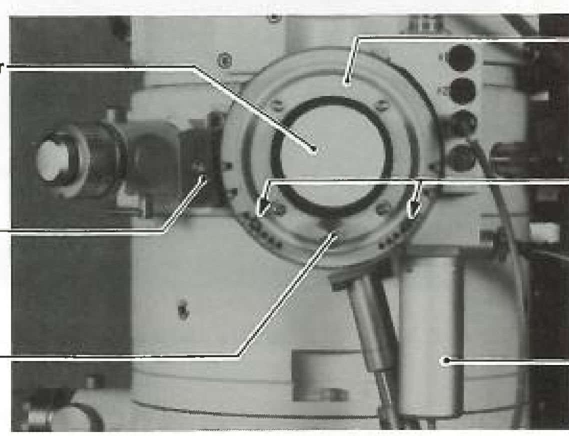


Fig. 4.1-3 Goniometer

No.	Name	Description
		of the specimen holder).
	Z control knob	Used for shifting the specimen vertically.
	X-tilt angle limiting screws (2 pcs.)	Used for confining the X-tilt angle.
	Lamp	Lights up when the motor is coupled to the goniometer.
	Motor	Drives the goniometer. To disengage, push the motor in the direction of the arrow.
⑥	Objective lens aperture assembly	Used for selecting, positioning, and aligning the objective lens apertures. See the description of the condenser lens aperture assembly (①).
⑦	Field limiting aperture assembly	Used for selecting, positioning, and aligning the field limiting apertures. See the description of the condenser lens aperture assembly (①).
⑧	Intermediate lens shifting screws (4 pcs.)	Used for aligning the image forming system.
⑨	Projector lens shifting screws (4 pcs.)	Used for aligning the image forming system.
⑩	Specimen shifting knobs	Used for shifting the specimen to select the desired field of view. The position of the selected field of view is displayed on the CRT (PAGE-2*) on control panel R1.
⑪	Beam stopper knob	Used for operating the beam stopper in order to block the direct beam spot in diffraction work.
⑫	Screen lever	Used for changing the small fluorescent screen position.
⑬	Camera chamber door handle	Used for opening and closing the camera chamber door. By turning the handle clockwise as far it will go, air is admitted into the viewing and camera chambers, and the camera chamber door opens. By turning the handle fully counterclockwise with the door kept closed by hand, the two chambers are evacuated.
⑭	Pedal switches	(see Fig. 4.1-4)
	X pedal switches	By stepping on one of the pedals, the specimen is tilted around the X-axis in one direction and by stepping on the other pedal, the specimen is tilted around the X-axis in the opposite direction.
	Y pedal switches	When a specimen rotation holder is used, the specimen is rotated in one direction by stepping on one of the pedals and rotated in the

* See Sect. 4.2.5.

No.	Name	Description
		opposite direction by stepping on the other pedal. When a specimen tilt holder is used, the specimen is tilted around the Y-axis (per-

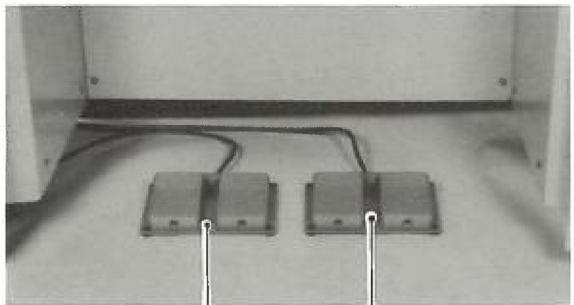


Fig. 4.1-4 Pedal switches

		pendicular to the axis of the specimen holder) in one direction by stepping on one pedal and tilted around the Y-axis in the opposite direction by stepping on the other pedal. Further, when a specimen elongating holder is used, the specimen is elongated by stepping on one pedal and compressed by stepping on the other pedal.

4.2 Control panels

4.2.1 Control panel L1

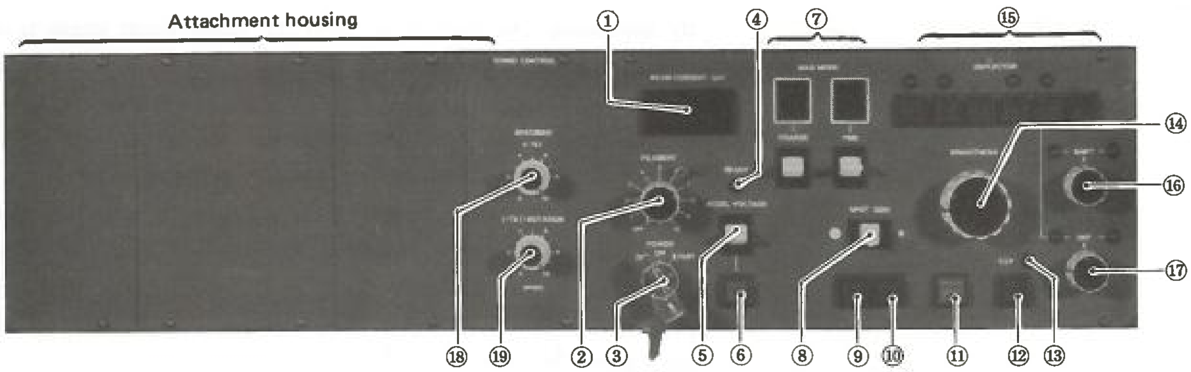


Fig. 4.2-1 Control panel L1

No.	Name	Description
L1-①	BEAM CURRENT	Indicates the sum of the beam current and the high voltage detecting current.
L1-②	FILAMENT	Used for controlling the electron gun filament heating current.
L1-③	POWER	Microscope main power switch.
L1-④	READY	Indicates that the microscope is ready for high voltage generation.
L1-⑤	ACCEL VOLTAGE	Setting this switch to the upper position raises the high voltage, and setting the switch to the lower position lowers the high voltage.
L1-⑥	HT	By depressing this button, the high voltage is switched on and the lamp lights up. By releasing the button, the high voltage is switched off and the lamp goes out.
L1-⑦	BIAS MODE (COARSE and FINE)	Used for selecting the electron gun bias. Setting either of these switches to the upper position increases the beam current (the value indicated by the indicators also increases), and brightens the image.
L1-⑧	SPOT SIZE	Setting this switch to the left position increases the spot size, and setting the switch to the right position decreases the spot size. The spot size value is displayed on the CRT (PAGE-1*) on control panel R1.

* See Sect. 4.2.5.

No.	Name	Description
L1-⑨	MDS	By depressing this button, the MDS (minimum dose system) is actuated, and the lamp lights up. When the button is released, the MDS ceases to operate, and the lamp goes out.
L1-⑩	OUF	By depressing this button, an optimum under-focus image is obtained and the lamp lights up. The image returns to the original state and the lamp goes out when the button is released.
L1-⑪	ROOM LIGHT	Used for turning on/off the room light.
L1-⑫	PHOTO	By depressing this button when the lamp is unlit, a film is advanced to the exposing position and the lamp lights up. By depressing this button when the lamp is lit, the film is exposed and after the exposure, the film is advanced from the exposing position and the lamp goes out.
L1-⑬	EXP	This lamp lights up and remains lit while the shutter is open.
L1-⑭	BRIGHTNESS	Used for converging and spreading the electron beam by varying the 2nd condenser lens current.
L1-⑮	DEFLECTOR	When one of these buttons is depressed, the depressed button lamp brightens and the current of the coil relating to the depressed button becomes variable with the DEF: X knob (control panel L1) and DEF: Y knob (control panel R1). The lamp darkens and the coil current is fixed when the button is released.
	OBJ STIG 1	Used when varying the objective lens stigmator coil current (or the intermediate lens stigmator coil current in the case of LOW MAG mode). By depressing this button, stigmator circuit 1 is actuated, the built-in lamp brightens, and the green lamp above the button lights up. The green lamp remains lit until the OBJ STIG 2 button is depressed.
	OBJ STIG 2	Same as the OBJ STIG 1 button except that stigmator circuit 2 is actuated by depressing this button. The green lamp remains lit until the OBJ STIG 1 button is depressed.
	COND STIG	Used when varying the condenser lens stigmator coil current.
	DARK TILT	Used when varying the condenser lens 1st and 2nd beam deflector coil current. By depressing this button, the condenser lens beam deflector DARK circuit is actuated, the built-in lamp brightens, and the green lamp above the button lights up. The green lamp remains lit until the BRIGHT TILT button is depressed.

No.	Name	Description
	BRIGHT TILT	Same as the DARK TILT button except that the condenser lens beam deflector BRIGHT circuit is actuated by depressing this button. The green lamp remains lit until the DARK TILT button is depressed.
	IMAGE SHIFT	Used for slightly shifting the field of view. By depressing this button, the 1st image shift coil power supply circuit is connected to DEF: X and Y, and the built-in lamp brightens. This button is effective only when the FUNCTION: MAG 1 or MAG 2 button (control panel R1) is depressed.
L1-⑯	SHIFT: X	Used for shifting the electron beam in the X direction by varying the condenser lens 1st beam deflector coil current. When this knob is set to its midway position, the left and right directional indicator lamps light up and when the knob is turned counterclockwise from the midway position the left lamp lights up and when it is turned clockwise the right lamp lights up.
L1-⑰	DEF: X	Used for varying the current of the X coil of the one set of coils selected by DEFLECTOR (control panel L1). When this knob is set to its midway position, the left and right directional indicator lamps light up and when the knob is turned counterclockwise from the midway position the left lamp lights up and when it is turned clockwise the right lamp lights up.
L1-⑱	X-TILT	Used for varying the specimen tilting speed around the X-axis (i.e., around the axis of the specimen holder).
L1-⑲	Y-TILT/ROTATION	Used for varying the specimen tilting speed around the Y-axis (i.e., around the axis perpendicular to the axis of the specimen holder) when a specimen tilt holder is used, the specimen rotation speed when a specimen rotation holder is used, and the specimen elongation rate when a specimen elongating holder is used.

4.2.2 Control panel R1

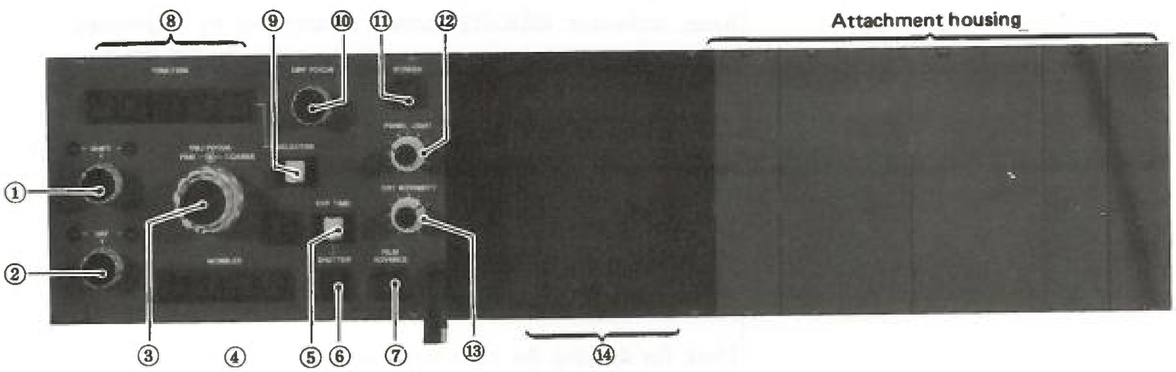


Fig. 4.2-2 Control panel R1

No.	Name	Description
R1-①	SHIFT: Y	Used for shifting the electron beam in the Y direction by varying the condenser lens 1st beam deflector coil current. When this knob is set to its midway position, the left and right directional indicator lamps light up and when the knob is turned counterclockwise from the midway position the left lamp lights up and when it is turned clockwise the right lamp lights up.
R1-②	DEF: Y	Used for varying the current of the Y coil of the one set of coils selected by DEFLECTOR (control panel L1). When this knob is set to its midway position, the left and right directional indicator lamps light up and when the knob is turned counterclockwise from the midway position the left lamp lights up and when it is turned clockwise the right lamp lights up.
R1-③	OBJ FOCUS	Used for adjusting the objective lens current (OM lens current in the case of LOW MAG mode) to focus the image.
	OBJ 16X	When this button is depressed, the button lamp lights up and the objective lens current range variable by the OBJ FOCUS knobs (control panel R1) enlarges 16 times.
R1-④	WOBBLER	Used for generating alternating current or imposing a small cyclic electrical variation on the related current or voltage.
	IMAGE X and Y	Used for focussing by depressing one of these buttons, the image wobbler coil current and condenser lens 1st beam deflector coil current are periodically varied. If the image is out of focus, it

No.	Name	Description
		wobbles in the X direction when the IMAGE X button is depressed and in the Y direction when the IMAGE Y button is depressed.
	OBJ	By depressing this button, the objective lens current is periodically varied, facilitating the current center alignment and astigmatism correction.
	HT	By depressing this button, the high voltage is periodically varied, facilitating the voltage center alignment.
R1-⑤	EXP TIME	Used for setting the exposure time in the manual exposure mode. Setting this switch to the left position decreases the exposure time, and setting the switch to the right position increases the exposure time. The exposure time set by this switch is displayed on the CRT (PAGE-1) on control panel Rl.
R1-⑥	SHUTTER AUTO	When this button is depressed, the lamp lights up and the shutter is automtically controlled. When the button is released the lamp goes out and the shutter is controlled manually.
R1-⑦	FILM ADVANCE AUTO	When this button is depressed, the lamp lights up and unused films are successively advanced to the exposing position without depressing the PHOTO button (control panel L1). When the button is released, the lamp goes out and no film is advanced to the exposing position unless the PHOTO button is depressed.
R1-⑧	FUNCTION	Used for selecting an image forming mode. The magnification or camera length in the selected mode can be varied with the SELECTOR switch (control panel R1), and is displayed on the CRT (PAGE-1) on control panel R1. The magnification or camera length set by the SELECTOR switch is stored so that even if another mode is once selected, the magnification or camera length can be set to the stored value by selecting the original mode again.
	MAG 1	Used for selecting the normal magnification mode.
	MAG 2	By depressing this button, a magnification of 5000X is obtained. In this mode, the magnification can be increased or decreased from 5000X with the SELECTOR switch. The magnification set in this mode is not stored.
	LOW MAG	Used for selecting the low magnification mode.
	SAM/ROCK	Used for selecting the selected area magnification mode (or the rocking mode when the ASID scanning device is used).

No.	Name	Description
	DIFF	Used for selecting the diffraction mode. In this mode, a total of 30-step camera lengths, i.e., the camera length for high resolution diffraction (1 step), those for selected area diffraction (15 steps), and those for high dispersion diffraction (14 steps) in the camera length ascending order, can be selected with the SELECTOR switch. The selected camera length is displayed on the CRT (PAGE-1) on control panel R1.
R1-⑨	SELECTOR	Used for varying the normal magnification when the FUNCTION: MAG 1 or MAG 2 button (control panel R1) is depressed, the low magnification when the FUNCTION: LOW MAG button is depressed, the selected area magnification (or the rocking angle in case the ASID is used) when the FUNCTION: SAM/ROCK button is depressed, and the camera length when the FUNCTION: DIFF button is depressed. Setting this switch to the left position decreases the value and setting the switch to the right position increases the value. The magnification or camera length set by this switch is displayed on the CRT (PAGE-1) on control panel R1.
R1-⑩	DIFF FOCUS	Used for varying the 1st intermediate lens coil current for focusing the field limiting aperture when the FUNCTION: SAM/ROCK button (control panel R1) is depressed, and for focusing the diffraction pattern when the FUNCTION: DIFF button is depressed.
R1-⑪	SCREEN	Used for changing the large fluorescent screen position (horizontal or vertical). The built-in lamp lights up and remains lit while the screen is at the vertical position.
R1-⑫	PANEL LIGHT	When this knob is turned fully counterclockwise, the panel light goes out and when it is turned clockwise, the panel light becomes brighter.
R1-⑬	CRT INTENSITY	Used for adjusting the brightness of the CRT (control panel R1).
R1-⑭	CRT	Used for displaying information (see Sect. 4.2.6) as requested through the keyboard.

4.2.3 Control panel L2

Fig. 4.2-3 Control panel L2

No.	Name	Description
L2-①	LIFT	Power on/off switch for the lift. By turning this switch ON and depressing the GUN AIR button (control panel L2), the lift is actuated to raise the electron gun.
L2-②	LENS POWER SUPPLY	By turning this switch OFF, the power supply circuits for all the lenses, beam deflector coils and stigmator coils are turned off and at the same time, the high voltage power supply is also turned off.
L2-③	ACCEL VOLTAGE	At OPERATE, the safety circuit for the high voltage is actuated, at TEST, the safety circuit is turned off and at OFF, the high voltage power supply is turned off.
L2-④	GUN AIR	The lamp lights up when this button is depressed and air is admitted into the anode chamber. When the LIFT switch (control panel L2) is set to ON, the lift is actuated to raise the electron gun after air is admitted into the anode chamber. When the button is released, the lamp goes out, the lift lowers to return the electron gun to its original position, and the anode chamber is evacuated.
L2-⑤	COL AIR	The lamp lights up and air is admitted into the column (except the viewing chamber) when this button is depressed. The lamp goes out and the column is evacuated when the button is released.
L2-⑥	ACD HEAT	Used for turning on/off the anticontamination device heating power.

No.	Name	Description
L2-⑦	BAKE OUT	Used for bake-out of the column.
L2-⑧	GUN SCAN	Used for finding the electron beam. The lamp lights up and the electron beam scans when this button is depressed.
L2-⑨	LENS	Power on/off switches for the respective lenses.
L2-⑩	PENNING GAUGE	Indicates the specimen chamber pressure. When lamp H is lit, read the upper (outer) scale and when lamp L is lit, read the lower (inner) scale.

4.2.4 Control panel R2

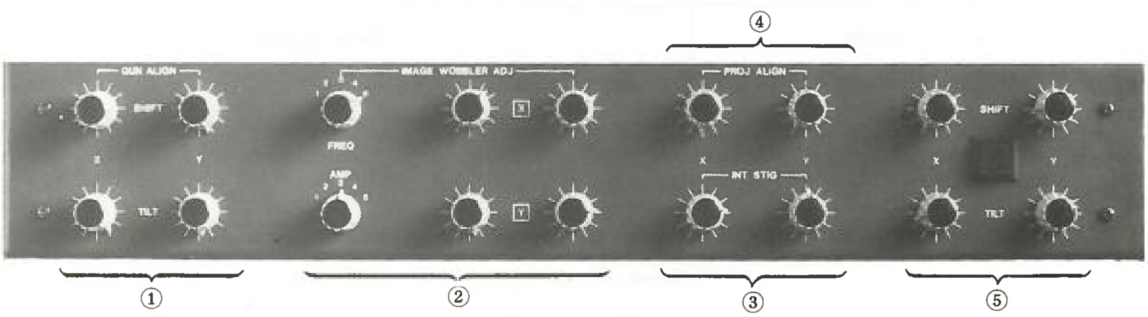


Fig. 4.2-4 Control panel R2

No.	Name	Description
R2-①	GUN ALIGN	Used for deflecting the electron beam entering the condenser lens in order to align the electron gun with the condenser lens.
	SHIFT: X and Y	Used for adjusting the current flowing through the electron gun 1st beam deflector coil in order to shift the electron beam.
	TILT: X and Y	Used for adjusting the current flowing through the electron gun 1st and 2nd beam deflector coils in order to tilt the electron beam.
R2-②	IMAGE WOBBLER ADJ	Used for aligning the condenser lens 1st and 2nd beam deflector coils. A pulsating current flows through the coils when the IMAGE X or Y button (control panel R1) is depressed.
	FREQ, AMP	Select the frequency and amplitude of the pulsating current.

No.	Name	Description
		Aligns the coils in the X and Y directions. The X knob functions when the IMAGE X button is depressed and the Y knob functions when the IMAGE Y is depressed.
R2-③	PROJ ALIGN: X and Y	Used for adjusting the projector lens beam deflector coil current in order to align the diffraction pattern center. These knobs are effective when the FUNCTION: DIFF button (control panel R1) is depressed.
R2-④	INT STIG: X and Y	Used for correcting the intermediate lens astigmatism.
R2-⑤	DF ALIGN	Used for obtaining a dark field scanning image when the microscope is used in conjunction with the ASID scanning device (optionally available). When this button is depressed, the built-in lamp lights up and the SHIFT and TILT knobs are made effective. This button is normally left released (lamp unlit).
	SHIFT	Used for adjusting the image shift coil current in order to shift the electron beam.
	TILT	Used for adjusting the image shift coil current in order to tilt the electron beam.

4.2.5 Keyboard (KB)

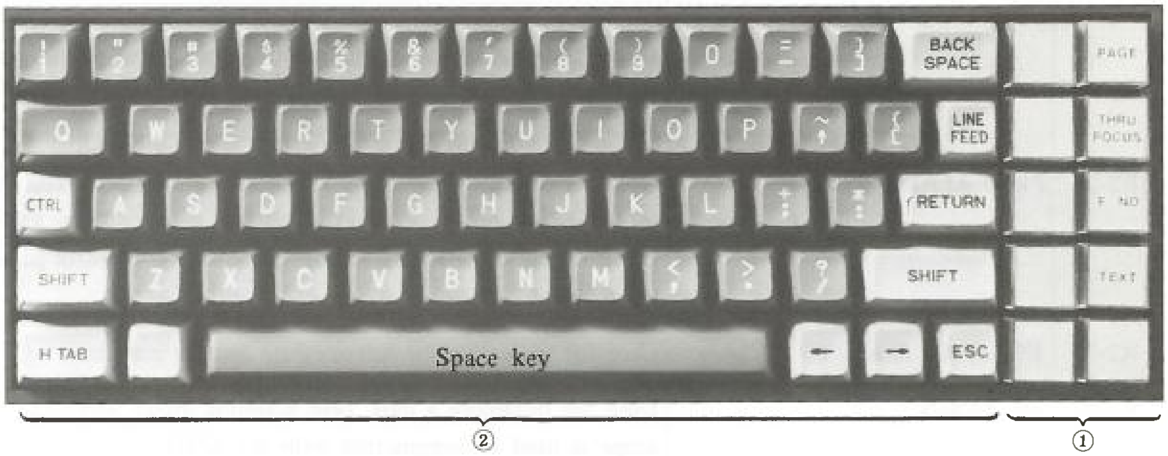


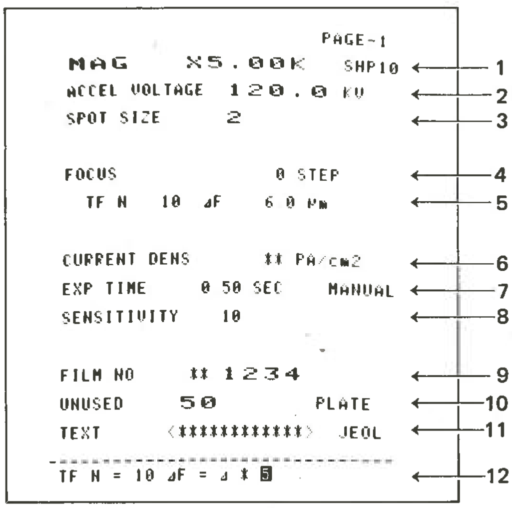
Fig. 4.2-5 Keyboard

No.	Name	Description
KB-①	PAGE	Every time this key is depressed, the PAGE displayed on the CRT (control panel R1) advances in the PAGE number in ascending order (PAGE-1 appears following PAGE-8). The displayed contents of each PAGE are as follows: PAGE-1: Magnification, type of objective lens pole piece, accelerating voltage, spot size, OBJ FOCUS knob position (step number), number of films to be exposed and focus step (step/film) for taking a through-focus series, current density on fluorescent screen, exposure time, exposure mode (automatic/manual), film sensitivity, OUF number, film number, number of unused films, type of camera, and TEXT (specimen name, etc.). PAGE-2: 3 specimen positions stored by the operator and the current specimen position (indicated by coordinates and graph). P, 0, 1, and 2 represent the coordinates of the current position and stored positions, respectively. In the graph, the ■ mark and x marks indicate the current position and stored positions, respectively. PAGE-3: Open/closed status of each vacuum valve (indicated by vacuum system diagram) and readings of 4 Pirani gauges. PAGE-4: Voltage at each lens circuit check point. PAGE-5: Voltage at each beam deflector circuit check point. PAGE-6: Voltage at each stigmator circuit check point. PAGE-7: Operator's memorandum. The information written on this page is stored in the memory. PAGE-8: A part of PAGE-1.

No.	Name	Description
	THRU FOCUS	Used for setting the number of films to be exposed and the focus step (step/film) for taking a through-focus series. By depressing this key, "TF N" and "ΔF" are displayed on the bottom margin of PAGE-1. To set the number of films and focus step, make the CRT display "TF N" and "ΔF" in the bottom margin of PAGE-1 by depressing this button, input the desired values through the keyboard, and depress the RETURN key. If an input value is out of the allowable range, "ERROR" is displayed. In such case, redepress the THRU FOCUS key (the erroneous input value and "ERROR" are now erased), input a value within the allowable range, and depress the RETURN key. When the RETURN key is depressed, the characters on the bottom line are erased.
	F NO	Used for setting the film number and the number of unused films. By depressing this key, "FILM-NO" and "UNUSED" are displayed in the bottom margin of PAGE-1. Then, input the film number and the number of unused films on the right of "FILM-NO" and "UNUSED", respectively, through the keyboard, and depress the RETURN key. If a number out of the allowable range is input, "ERROR" is displayed. In such case, redepress the F NO key (the input number and "ERROR" are now erased), input a proper number, and then depress the RETURN key. When the RETURN key is depressed, the characters on the bottom line are erased and the input numbers are stored in the memory.
	TEXT	Used for writing information on the TEXT line of PAGE-1 and on any line of PAGE-7. By depressing this key once, "TEXT" is displayed in the bottom margin of PAGE-1 and by depressing this key twice, PAGE-7 is displayed. Further, by depressing this key three or more times, the information on PAGE-7 is erased. If information is to be written on the TEXT line of PAGE-1, depress this key once to make the CRT display "TEXT" in the bottom margin of PAGE-1, input required characters and symbols through the keyboard (see KB- 2), and depress the RETURN key. By so doing, the TEXT information written at the bottom moves to the TEXT line, and is stored in the memory. At the same time, "TEXT" displayed at the bottom is erased.
	PRINT	By depressing this key, the information displayed on the CRT is recorded by the printer (attachment).
KB-②	BACK SPACE	Used for column alignment (Subsect. 5.3.2).
	LINE FEED	When depressed, the cursor on PAGE-7 moves downwards (Subsect. 5.2.11f).
	CTRL	Used to display the * mark on PAGE-1 (Subsect. 5.2.11e).
	RETURN	See Subsect. 5.2.11.
	SHIFT	Used to display the upper one of two characters on the key.
	H TAB	Not used.

No.	Name	Description
	ESC	Used to suspend the automatic operation being carried out as requested through the key board.
	← and →	Used to move the cursor on the CRT left and right.
	Space key	Used to erase the character under the cursor on the CRT.
	Other keys	Used to typewrite the desired characters under the cursor on the CRT.

4.2.6 CRT display



1: Next to "MAG", the magnification (or camera length) is displayed. The value of magnification or camera length can be varied by manipulating the SELECTOR switch (control panel R1). The displayed value is printed on the film.
At the right end of this line, the name of the objective lens pole piece being used is displayed (Subsect. 5.2.11e).

2: The accelerating voltage displayed on this line is generated by depressing the HT button (control panel L1). The accelerating voltage can be varied by manipulating the ACCEL VOLTAGE switch (control panel L1), and the displayed value is printed on the film.

3: A number indicating the electron beam spot size is displayed. The spot size can be varied by manipulating the SPOT SIZE switch (control panel L1). The larger the displayed number, the smaller the spot size.

4: The OBJ FOCUS knob (control panel R1) turning amount is displayed in terms of number of OBJ FOCUS: FINE knob steps. (When the OBJ 16X button switch is on, the amount is not displayed). The displayed number is set to 0 when any of the magnification, accelerating voltage and imaging mode is changed.

5: The number of films to be exposed, an amount of focus change per notch of the OBJ FOCUS: FINE knob (control panel R1), and a number of OBJ FOCUS: FINE knob notches per film for taking a through-focus series are displayed. The displayed values can be varied through the keyboard (Subsect. 5.2.11n).

6: The current density on the fluorescent screen is displayed.

7: Next to "EXP TIME", the exposure time is displayed. In the case of manual exposure, the displayed value can be varied by manipulating the EXP TIME switch (control panel R1). At the end of this line, "AUTO" (auto-

matic exposure) or "MANUAL" (manual exposure) is displayed. The desired exposure mode can be selected with the SHUTTER AUTO button (control panel R1).

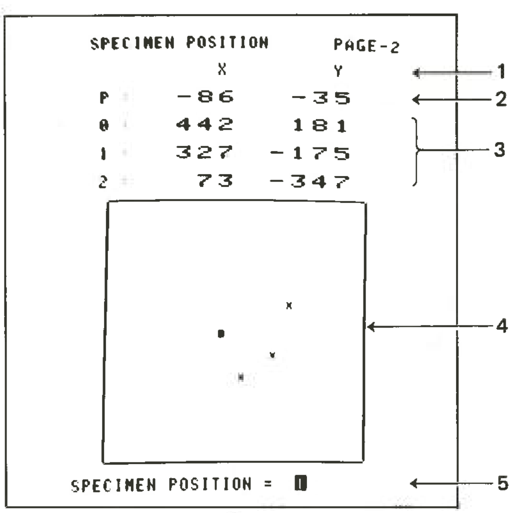
8: Next to "SENSITIVITY", a number indicating the exposure meter sensitivity is displayed. The larger the displayed number, the lower the sensitivity and the longer the exposure time. The sensitivity can be varied through the keyboard (Subsect. 5.2.11ℓ). Next to "OUF", an OUF number is displayed (Subsect. 5.2.11o).

9: The film number is displayed. Every time a film is exposed, the displayed number (low order four digits) advances by one. The film number can be changed through the keyboard and nonnumeric characters can be written into high order two digits (Subsect. 5.2.11j). The displayed value is printed on the film.

10: Next to "UNUSED", the number of unused films is displayed. Every time a film is exposed, the displayed number is reduced by one. This number can be changed through the keyboard (Subsect. 5.2.11j).
At the right end of this line, the type of film (camera) as selected with keyboard is displayed (Subsect. 5.2.11k).

11: On this line, the operator can write the specimen name, etc. through the keyboard. The displayed contents are printed on the film (Subsect. 5.2.11g).

12: A desired character can be written through the keyboard at the position marked with ■. By depressing the ← or → key, the ■ mark can be shifted leftward or rightward and by depressing the space key, the character in the ■ mark can be erased. Further, by depressing the RETURN key, the characters written on this line are erased and are stored in the memory.

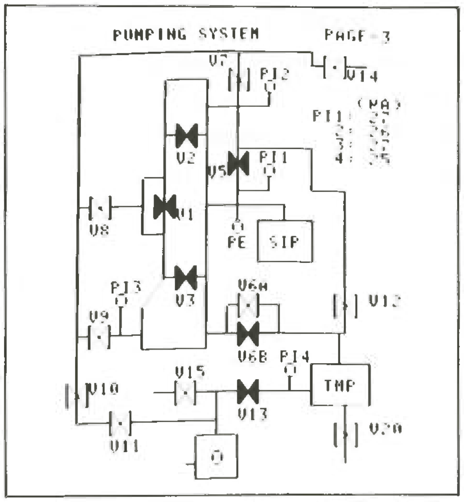


PAGE-2 is displayed by depressing the SP PO key on the keyboard.

1: X means the horizontal direction on the CRT or the X direction (specimen holder axial direction) on the specimen. When the left specimen shifting knob is turned, the specimen horizontally shifts on the CRT. Y means the vertical direction on the CRT.

2: The coordinates of the current specimen position are displayed. The current specimen position is represented by the ■ mark in the graph.

3: The coordinates of each stored specimen position are displayed. The stored specimen positions are represented by the x marks in the graph.



4: A circle inscribed in this frame corresponds to the specimen grid size.

5: This is displayed by depressing the keyboard (see Subsect. 5.2.11i).

PAGE-3 shows the status of the vacuum system.

⋈ : Indicates that the valve is closed.

⧓ : Indicates that the valve is open.

		PAGE-4	
LENS		(X20 0K 120 0KV)	
COND	1	3.42	1
	2	6.51	2
OBJ		5.02	3
OM		0.00	4
INT	1	4.83	5
	2	3.07	6
	3	4.42	7
PROJ		7.57	8
		JEOL	

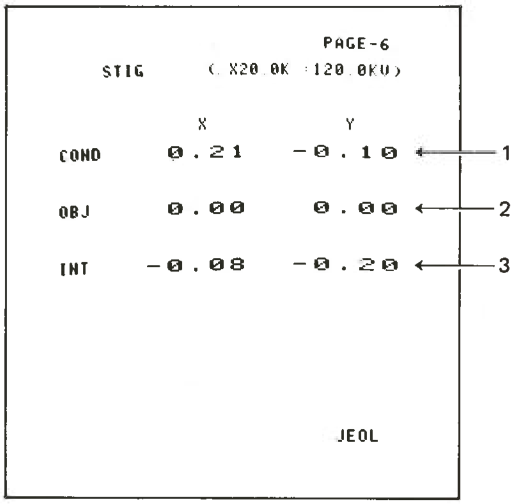
PAGE-4 shows the voltage at each lens circuit check point.

1: 1st condenser lens
2: 2nd condenser lens
3: Objective lens
4: OM lens
5: 1st intermediate lens
6: 2nd intermediate lens
7: 3rd intermediate lens
8: Projector lens

			PAGE-5	
ALIGN		(X20 0K	120 0KV)	
		X	Y	
GUN	1	0.43	0.16	1
	2	0.00	0.10	2
SPA		0.00	0.00	3
CLA	1	0.09	0.01	4
	2	0.01	0.00	5
IS	1	-0.35	-0.25	6
	2	-1.04	-0.74	7
PLA		-3.47	3.88	8
			JEOL	

PAGE-5 shows the voltage at each beam deflector circuit check point.

1: Electron gun 1st beam deflector coil
2: Electron gun 2nd beam deflector coil
3: Spot alignment coil
4: Condenser lens 1st beam deflector coil
5: Condenser lens 2nd beam deflector coil
6: 1st image shift coil
7: 2nd image shift coil
8: Projector lens beam deflector coil

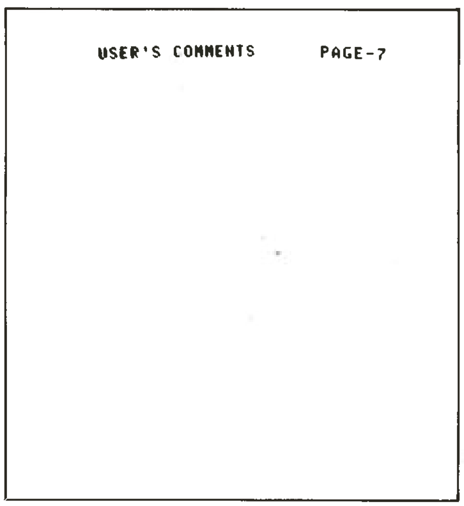


PAGE-6 shows the voltage at each stigmator circuit check point.

1: Condenser lens stigmator coil

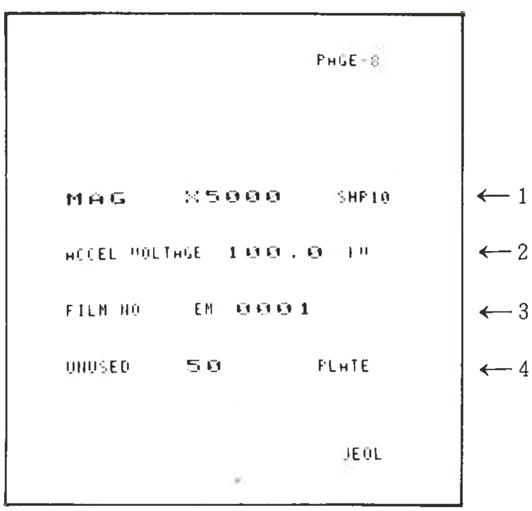
2: Objective lens stigmator coil

3: Intermediate lens stigmator coil



A desired character can be written through the keyboard at the position marked with ■. By depressing the ← or → key, the ■ mark can be shifted leftward or rightward, and by depressing the space key, the character in the ■ mark can be erased. Further, by deprssing the RETURN key, the ■ mark can be brought to the first character position on the next line.

If the TEXT key is depressed with characters written on this PAGE, all the characters are erased (the erased characters are not stored in this case), and the ■ mark returns to the initial position. The written characters are stored in the memory by depressing the PAGE key.



Same as item 1 on PAGE-1.

Same as item 2 on PAGE-1.

Same as item 9 on PAGE-1.

Same as item 10 on PAGE-1.

5. OPERATION

5. OPERATION

This chapter describes the operation procedures up to and including image recording. Method A covers the startup, image recording, and shutdown procedures, method B the necessary procedure for axis alignment, and method C the procedures for routine observation. It is advisable to become familiar with method A before attempting methods B and C. The symbols L1, L2, R1, R2, and KB appearing in parentheses after the names of panel controls designate the respective control panels (see Fig. 3.5-1).

Two objective lens pole pieces, the SHP and SAP, are provided in this instrument. The SHP is used for high-resolution and high-magnification observation, and the SAP allows work requiring larger tilts of the specimen. This chapter describes all the operation procedures in the case of using the SHP. If the SAP is to be used, see Sect. 5.10.

5.1 Emergencies

5.1.1 Power suspension

The microscope automatically shuts down safely. When power is restored, it is necessary to manually restart the microscope.

5.1.2 Cooling water suspension

If water suspension continues for some time, the high-voltage power and lens power supplies are turned off and the vacuum system goes into the protected state. When the supply of cooling water recommences, the vacuum system is automatically restored to its original state, but the high-voltage power and lens power must be manually restored.

5.1.3 Faulty operation

The microscope is fully and automatically protected by safety devices.

5.2 Method A

It is advisable to become familiar with method A before attempting methods B and C. Procedures detailed in this section are skeletonized in the sections on methods B and C.

5.2.1 Startup procedure

1. Make sure that:
   a. The LIFT, LENS POWER SUPPLY, and ACCEL VOLTAGE switches (L2-1, 2, and 3) are set at ON, ON, and OPERATE, respectively.
   b. The GUN AIR and COL AIR button switches (L2-4 and 5) are off.
   c. The compressed air pressure is 0.35 to 0.45 MPa (gage pressure).
2. Open the cooling water faucet.
3. Turn on the mains power switch on the distribution board.
4. Insert the key into the POWER switch (L1-3), turn the key to START via ON, keep it at START for five seconds, then release the key (the key returns to ON), and wait for the READY lamp (L1-4) to light up. While waiting, carry out film loading and specimen preparation (Sects. 5.2.2 and 5.2.3).

   Note: As soon as the key of the POWER switch (L1-3) is turned to ON, the PC (printed circuit) boards are checked by the self-diagnostic function, and if any PC boards are found abnormal, their names are displayed on the CRT (R1-14) for about 10 seconds.

5.2.2 Film loading

5.2.2a Loading films into the dispensing magazine

1. Insert an unexposed film into each cassette with the emulsion side facing up under a safelight in a dark room (Fig. 5.2-1).
2. Remove the lid from the dispensing magazine and fully depress the bottom plate until it is clamped.
3. Place the loaded cassettes in the dispensing magazine and replace the magazine lid. Up to 50 cassettes can be loaded in one magazine.

   Caution: Do not mistake the dispensing magazine for the receiving magazine (see Fig. 5.2-4). The dispensing magazine is provided with a bottom plate, but the receiving magazine is without it.

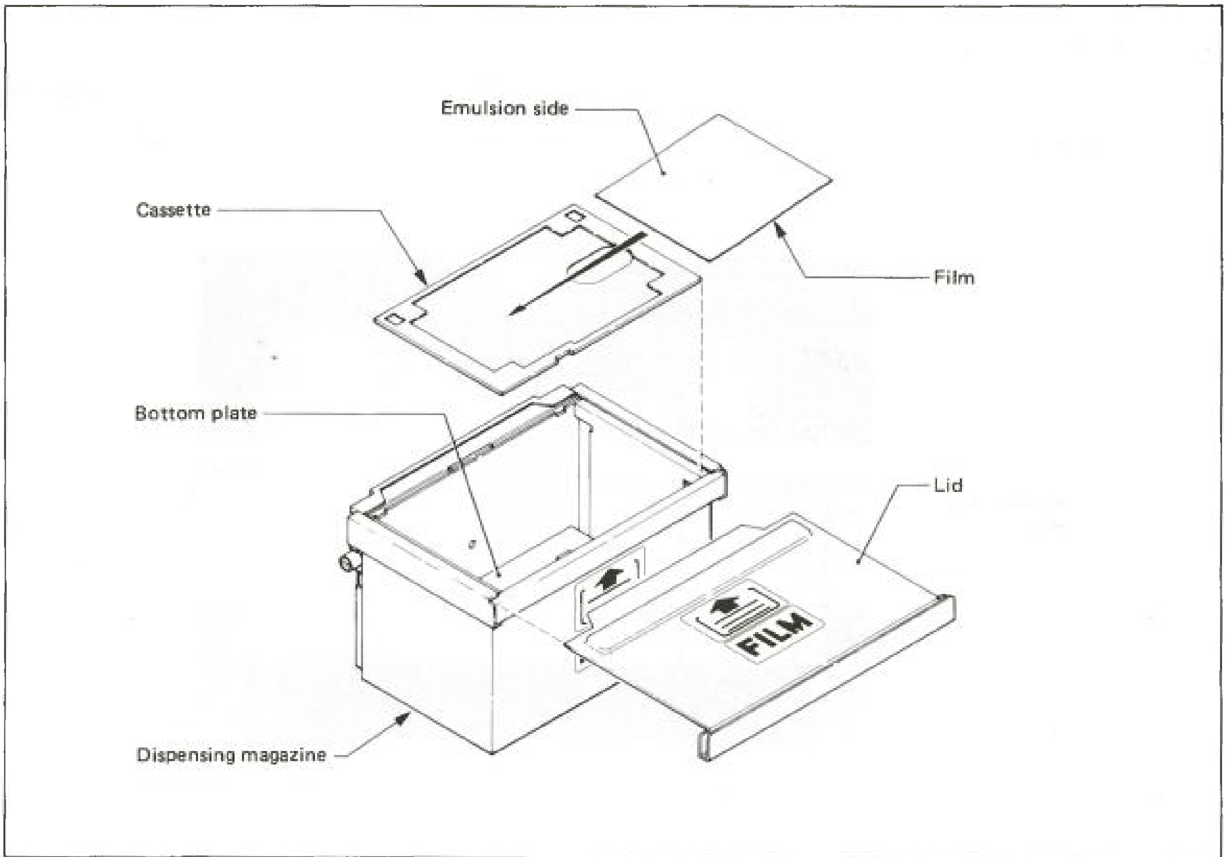


Fig. 5.2-1 Loading films into the dispensing magazine

5.2.2b Inserting (or removing) the magazines into (or from) the camera chamber

1. Make sure there is no unused film in the camera chamber. The number of unused films is indicated after "UNUSED" on PAGE-1 (Fig. 5.2-2) displayed on the CRT (R1-14). That is, if the indicated number is 0, there is no unused film in the camera chamber. If PAGE-1 is not being displayed on the CRT, make the CRT display PAGE-1 in accordance with 5.2.11a.
2. Make sure the FILAMENT knob (L1-2) is set at OFF and the PHOTO button lamp (L1-12) is not lit. If the PHOTO button lamp is on, turn off the FILM ADVANCE AUTO button switch (R1-7) and depress the PHOTO button.
3. Turn the camera chamber door handle clockwise until it stops (Fig. 5.2-3).

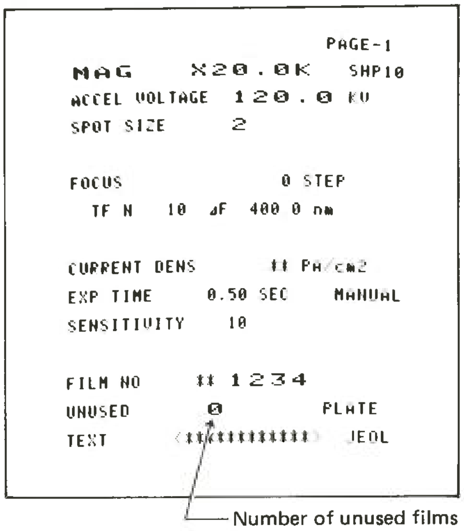


Fig. 5.2-2 PAGE-1

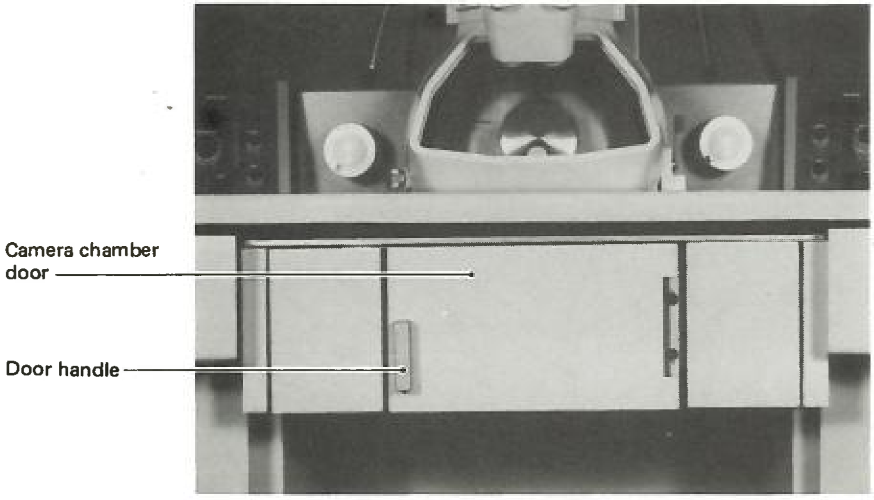


Fig. 5.2-3 Camera chamber

4. Open the camera chamber door.

   Note: Carry out Steps 5 to 9 as quickly as possible so as to avoid exposing the camera chamber to the atmosphere for longer than absolutely necessary.

5. Draw out the magazine stand by pulling the handle (Fig. 5.2-4).
6. If there is an empty dispensing magazine in the magazine stand, remove it by lifting it out. Then place the

dispensing magazine loaded with unexposed films squarely in the magazine stand.

Caution: If the magazine is not placed squarely in the magazine stand, it will be impossible to insert the magazine stand smoothly.

Notes: 1. Two dispensing magazines and two receiving magazines (Fig. 5.2-5) are provided in order to enhance throughput. That is to say, while one dispensing magazine is being used, the other can be kept in the desiccator (optionally available) so that the loaded films are ready and de-moisturized when needed. Also, as one receiving magazine is being filled during the course of photography, the second one can be kept handy, ready for the next sequence of filming.

2. When handling the magazines, hold them so as to prevent the magazine lid from dropping out.

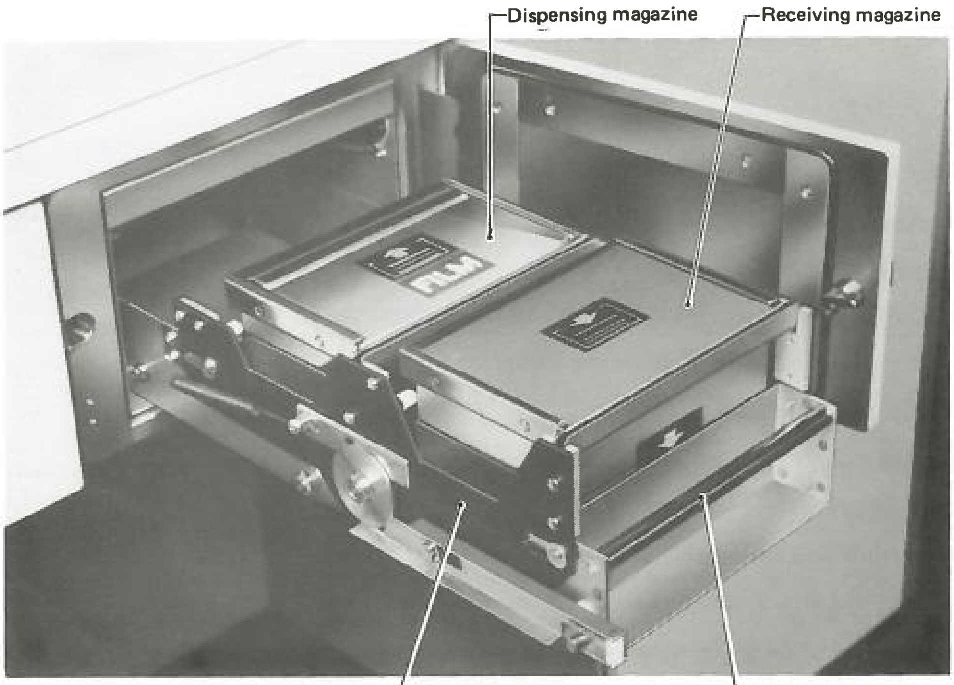


Fig. 5.2-4 Magazine stand

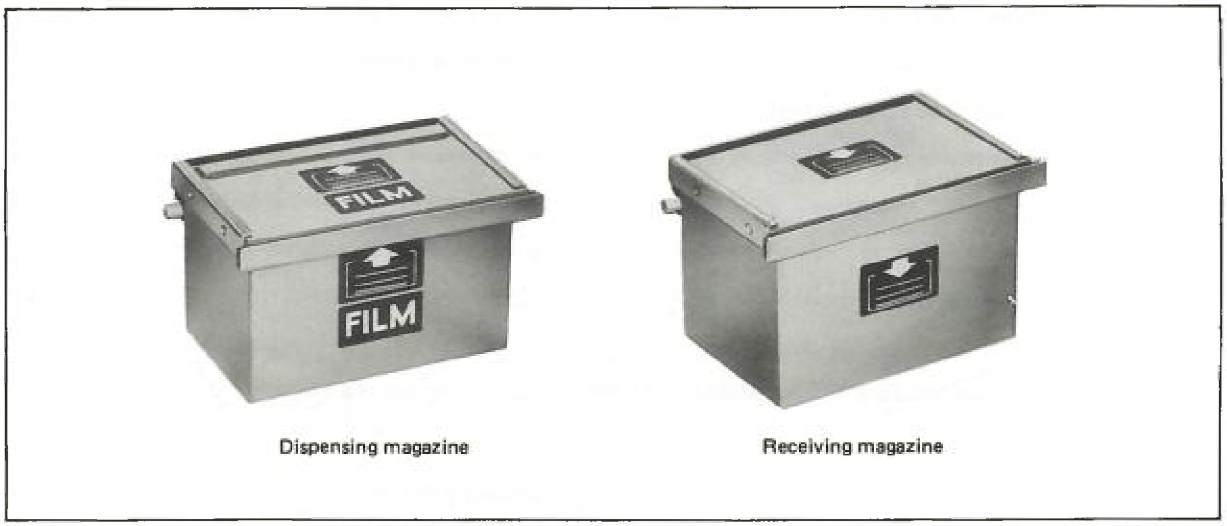


Fig. 5.2-5 Magazines

7. If there is a receiving magazine loaded with exposed films in the magazine stand, remove it by lifting it out and replace it with an empty receiving magazine.

   Caution: Never remove the lid from a loaded magazine unless dark room facilities are available.

8. Push the magazine stand fully in.
9. Close the camera chamber door and, while holding it closed, turn the door handle counterclockwise as far as it will go.

   Caution: Before closing the camera chamber door, check the O-ring and its contact surfaces for dust, lint, etc. A dirty O-ring may adversely affect the camera chamber vacuum.

10. Write the number of unused films (the number of films loaded in the dispensing magazine) on the CRT.

10a. Let the CRT display PAGE-1 (see Sect. 5.2.11a).

10b. Depress the F NO key (KB-1).

10c. Set the UNUSED number (Fig. 5.2-6) to accord with the number of unused films (see Sect. 5.2.11f).

10d. Depress the C/R key (KB-2).

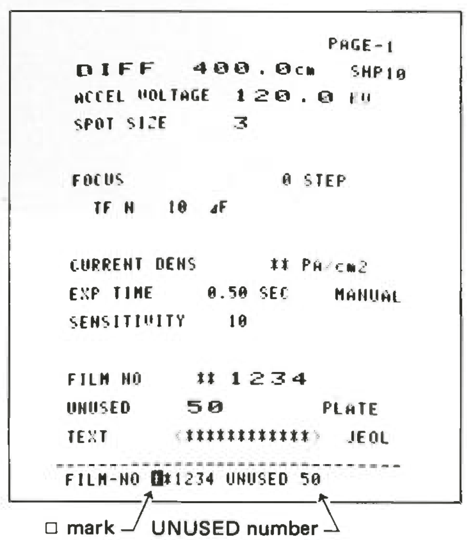


Fig. 5.2-6 Writing the UNUSED number

5.2.3 Specimen preparation

This section describes how to insert the specimen in (and remove it from) the specimen holder.

1. Remove the specimen holder and specimen holder stand from the EM-SQH specimen holder box (Fig. 5.2-7).

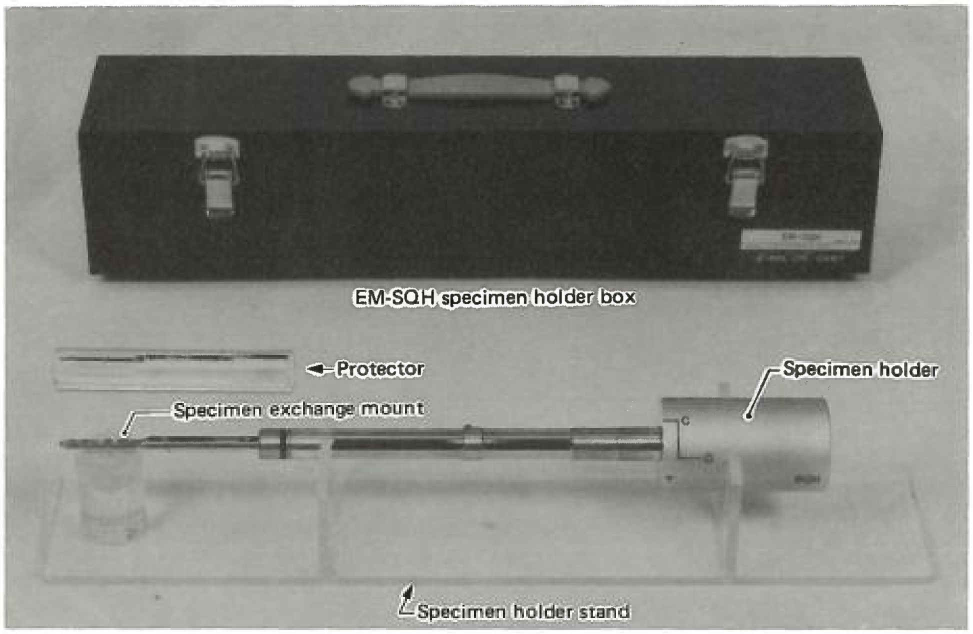


Fig. 5.2-7 EM-SQH specimen holder box and stand

2. Place the specimen exchange mount on the specimen holder stand so that the mount orientates as shown in Fig. 5.2-8.
3. Remove the protector from the specimen holder and place the specimen holder on the specimen holder stand.
4. Raise the specimen clamp by pushing the claw in the direction indicated by the arrow (see Fig. 5.2-9).
5. Insert the specimen and secure it with the clamp by returning the claw to its original position. Make a note of the type and name of the specimen and the holder specimen number inscribed on the holder's side.
6. Cover the specimen holder with the protector and place the specimen holder on the specimen holder stand.

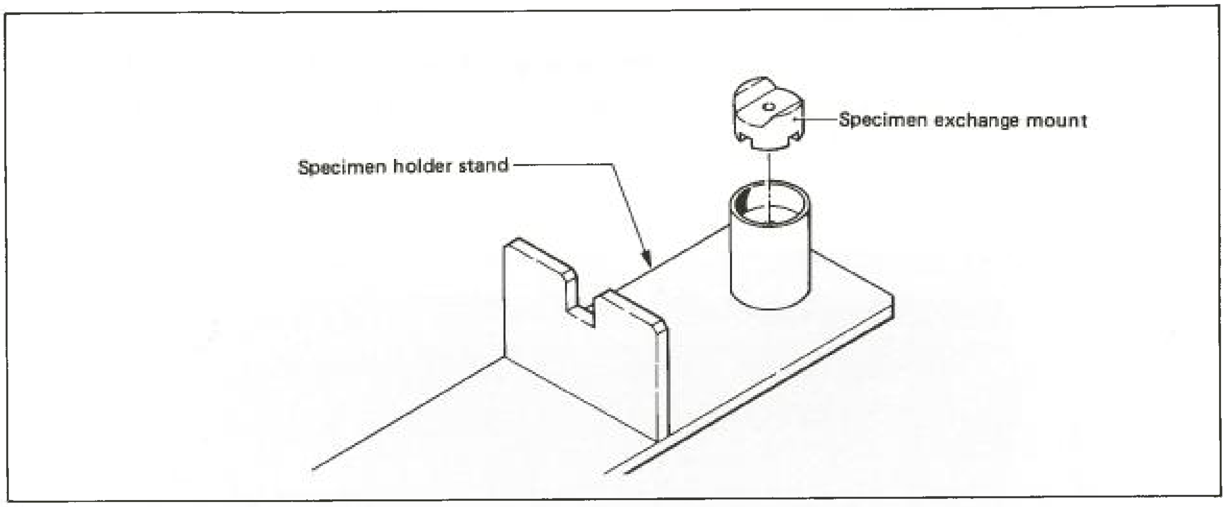


Fig. 5.2-8 Installing the specimen exchange mount

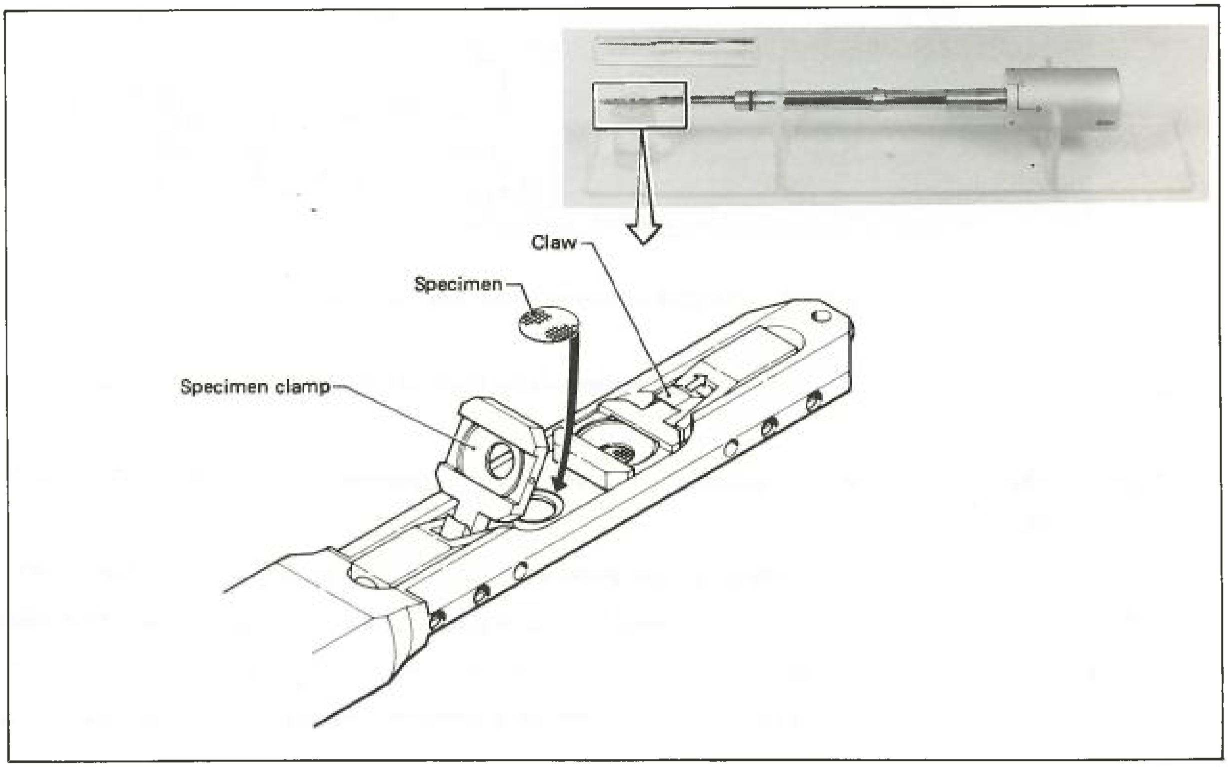


Fig. 5.2-9 Specimen exchange

5.2.4 Electron beam generation

1. Confirm every three months that the reading of the high-voltage generating tank gas pressure meter (on the upper part of the tank) is between 0.4 and 0.6. If the reading is below 0.4, replenish the tank with Freon gas referring to Chapter 6.
2. Confirm that the READY lamp (L1-4) is lit and the FILAMENT knob (L1-2) is set at OFF.
3. Set the desired accelerating voltage.
   3a. Let the CRT display PAGE-1 (Fig. 5.2-10; see Sect. 5.2.11a).
   3b. Manipulate the ACCEL VOLTAGE switch (L1-5) so as to obtain the desired ACCEL VOLTAGE value on the CRT.

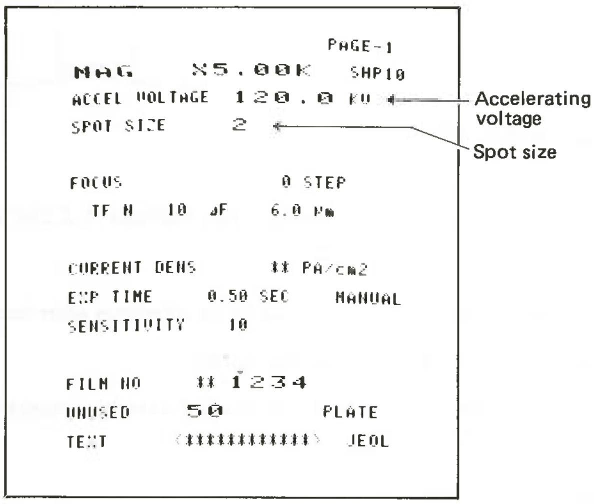


Fig. 5.2-10 Accelerating voltage and spot size

Table 5.1 Accelerating voltage and related detecting current values

Accelerating voltage (kV)	BEAM CURRENT reading
40	23 ~ 24
60	35 ~ 36
80	47 ~ 48
100	58 ~ 60
120	70 ~ 73

4. Depress the HT button (L1-6) (the built-in lamp lights up) and confirm that the BEAM CURRENT (L1-1) reading (detecting current) becomes stable in the applicable range shown in Table 5.1. If the BEAM CURRENT reading does not become stable, raise the accelerating voltage to the next higher value with the ACCEL VOLTAGE switch (L1-5) and after two or three seconds, return the accelerating voltage to the original value.

   Notes: 1. Setting the ACCEL VOLTAGE switch to the upper position raises the accelerating voltage. The accelerating voltage is displayed on PAGE-1 on the CRT.

   2. If the BEAM CURRENT reading becomes excessively high, the supply of high voltage power is automatically turned off and the BEAM CURRENT reading becomes 0. In such case, reduce the accelerating voltage to the next lower value and depress the HT button again.

5. Retract the condenser lens aperture, objective lens aperture, and field limiting aperture from the electron beam path by setting the lever of each aperture assembly (Fig. 5.2-11) to the right side.

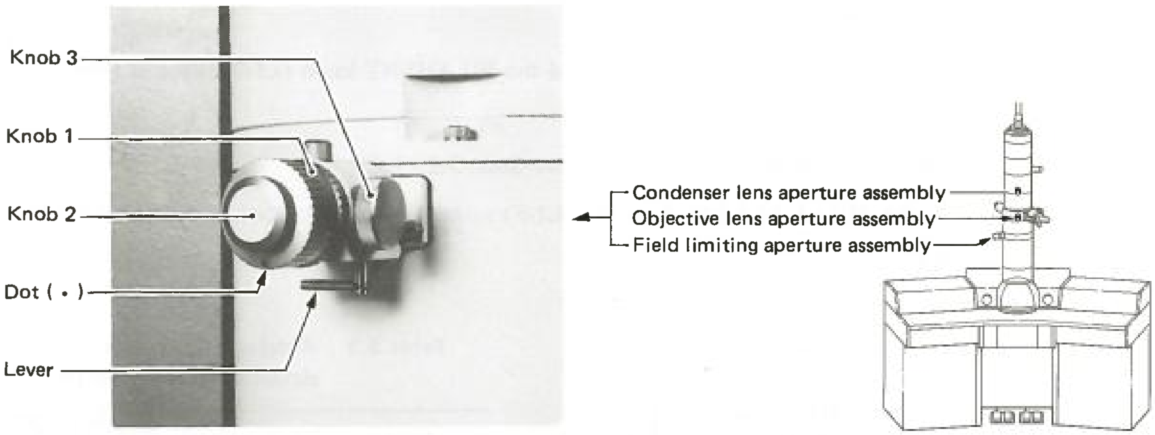


Fig. 5.2-11 Aperture assembly

6. Make sure that the dispensing and receiving magazines are in the camera chamber (see Subsect. 5.2.2b), and the specimen holder is in the "alignment position".

   Note: The "alignment position" is the fully turned position in the counterclockwise direction after inserting the holder into the beam path (see Subsect. 5.2.6) and pulling the holder.

   Caution: Do not generate any electron beam when the camera chamber is not loaded with two magazines

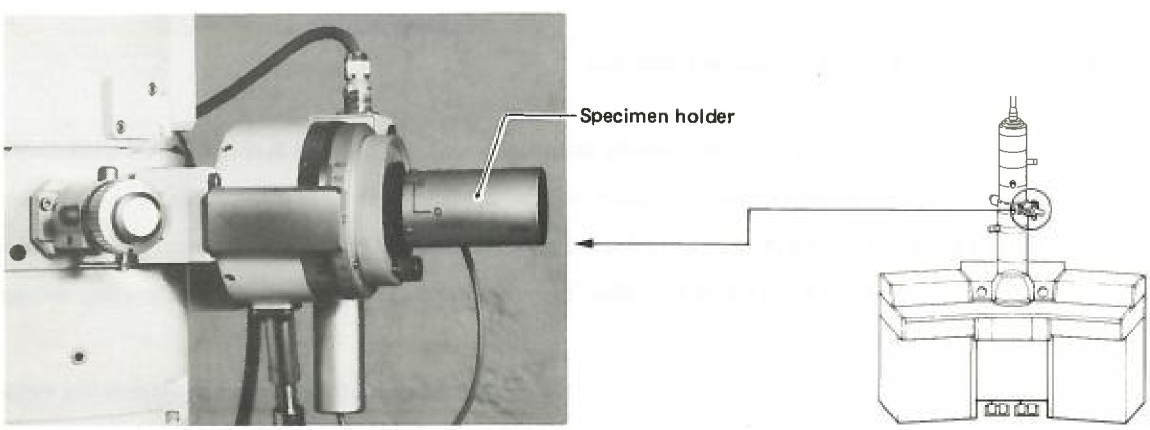


Fig. 5.1-12 Specimen holder installed in the column

7. Let the CRT display PAGE-3 (Fig. 5.2-13) (see Sect. 5.2.11a), and confirm that viewing chamber airlock valve V3 is open. If the large fluorescent screen is raised, lower it by depressing the SCREEN button (R1-11).

   Note: If V3 is closed, the electron beam cannot be generated.

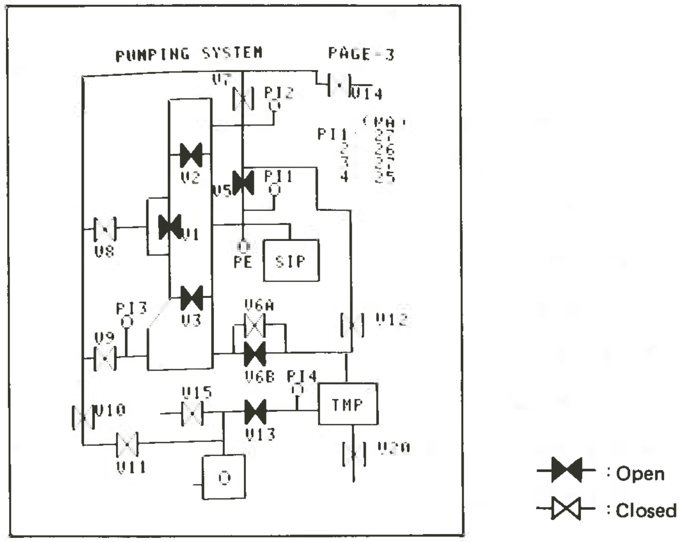


Fig. 5.2-13 PAGE-3

8. After adjusting the BIAS MODE: COARSE and FINE switches (L1-7) so that the BIAS MODE indicator reads 70 to 80, turn the FILAMENT knob (L1-2) clockwise to the stopper while watching the BEAM CURRENT meter (L1-1). If the BEAM CURRENT reading does not change when the FILAMENT knob is turned, electron gun filament breakage is indicated (for details on filament replacement, refer to Sect. 6.1).
9. Darken the room and adjust the control panel illumination with the PANEL LIGHT knob (R1-12).
10. Obtain a spot size of 2.

    10a. Let the CRT display PAGE-1 (Fig. 5.2-10; see Sect. 5.2.11a).

    10b. Set the SPOT SIZE value on PAGE-1 to 2 with the SPOT SIZE switch (L1-8).
11. Confirm that all the LENS button switches (L2-9) are on, depress the FUNCTION: MAG2 button (R1-8), and turn the BRIGHTNESS knob (L1-14). When the screen is illuminated by the electron beam, proceed to Step 17. If the fluorescent screen is not illuminated, carry out the following steps.

    Note: The BRIGHTNESS knob turns endlessly. If this knob is excessively turned, however, weak peep sounds will be heard.
12. Set the SHIFT: X and Y knobs (L1-16, R1-1) to the midway position, release the PROJ button switch (L2-9), and turn the BRIGHTNESS knob (L1-14). If no illumination is observed on the screen, proceed to Step 13. When illumination appears on the screen, manipulate the SHIFT: X and Y knobs and BRIGHTNESS knob for brighter illumination; then depress the PROJ button switch and achieve brightest illumination with the above-mentioned knobs. Then proceed to Step 17.

    Note: When the SHIFT: X and Y knobs (L1-16, R1-1) are set to the midway position, the left and right directional indicator lamps above each knob light up.

13. Set the GUN ALIGN: SHIFT: X, Y and TILT X, Y knobs (R2-1) to their midway positions, turn on the GUN SCAN button switch (L2-8), and then manipulate the BRIGHTNESS knob (L1-14) so that the fluorescent screen is illuminated by the electron beam.

    Note: The GUN ALIGN: SHIFT: X, Y and TILT X, Y knobs are of the five-turn type.

14. Manipulate the GUN ALIGN: SHIFT: Y and TILT: Y knobs (R2-1) and the BRIGHTNESS knob (L1-14) so as to obtain the brightest illumination at the screen center.
15. Release the GUN SCAN button (L2-8).
16. Manipulate the GUN ALIGN: SHIFT: X and TILT: X knobs (R2-1) and the BRIGHTNESS knob (L1-14) so as to obtain the brightest illumination. If the illumination becomes glary in the course of this operation, stop manipulating the knobs, depress the PROJ button (L2-9) and manipulate the knobs again so as to obtain the brightest illumination.

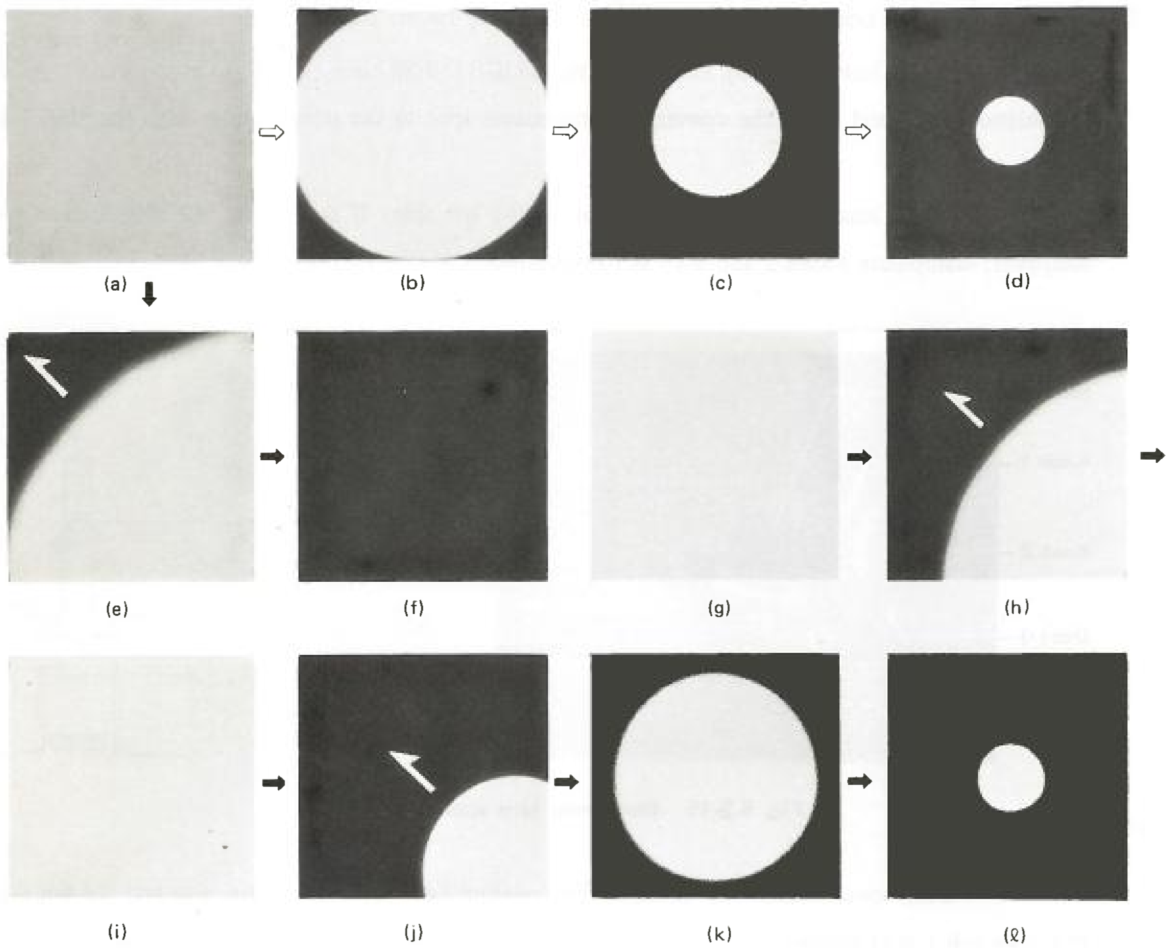
    Caution: Do not allow the illumination to become too bright with the PROJ button switch (L2-9) off; otherwise the fluorescent screen material may be damaged by excessive electron bombardment.

17. Converge the electron beam with the BRIGHTNESS knob (L1-14) (see Fig. 5.2-14).

    If the illumination becomes circular and the illumination spot converges on the screen as shown by a to b, c and d in Fig. 5.2-14 (and then expands), insert the condenser lens aperture in accordance with Sect. 5.2.5.

    If the illumination shifts off the screen as shown by a to e and f, proceed as follows:

    Eliminate the shadow by shifting the illumination in the direction of the arrow (e) with the SHIFT knobs (L1-16, R1-1) and then reconverge the electron beam with the BRIGHTNESS knob (L1-14) as shown by e to g and h. Repeat this shift and convergence procedure (h to i and j) until the illumination spot converges on the screen as shown by j to k and ℓ.



a ⇨ b ⇨ c ⇨ d : Correctly aligned

a ➡ e ➡ f or a ➡ i ➡ j : Incorrectly aligned

e ➡ g ➡ h ➡ i ➡ j ➡ k ➡ ℓ : Alignment procedure

Fig. 5.2-14 Condenser lens alignment

5.2.5 Inserting the condenser lens aperture into the beam path

1. Depress the MAG2 button (R1-8), manipulate the BRIGHTNESS knob (L1-14) so as to obtain the smallest illumination spot, and bring the converged illumination spot to the screen center with the SHIFT knobs (L1-16, R1-1).
2. Set the condenser lens aperture assembly lever to the left side. If this causes the illumination spot to disappear, manipulate knobs 2 and 3 so as to reproduce the spot (Fig. 5.2-15).

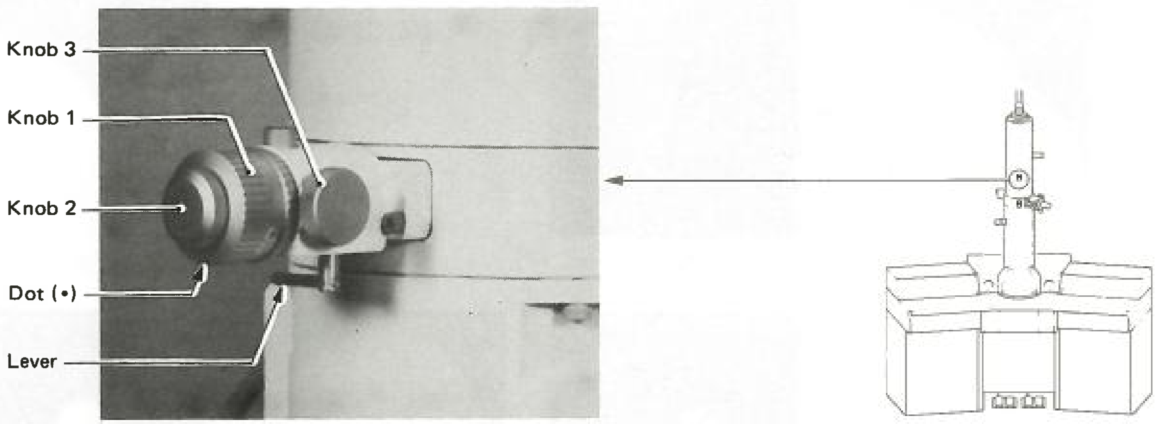


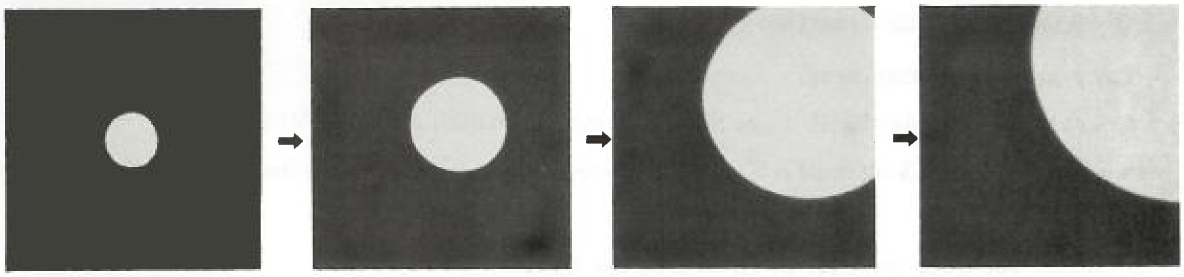
Fig. 5.2-15 Condenser lens aperture assembly

3. Select the desired aperture size with knob 1. The relation between the aperture size and the dot (•) position on knob 1 is as follows:

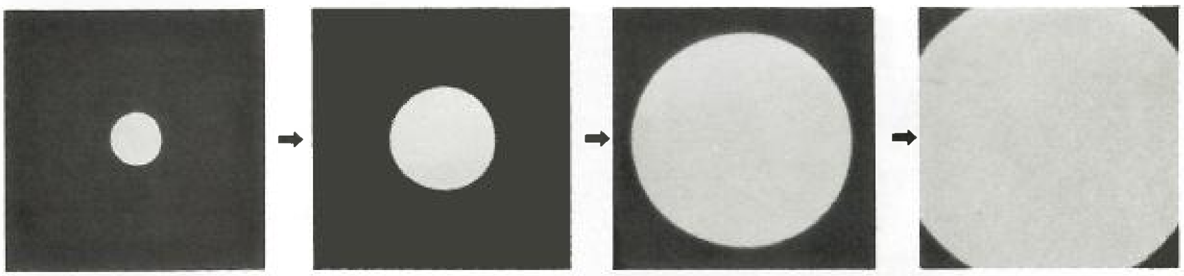
Dot position	Aperture size
6 o'clock	Large
Half past 7	Medium
9 o'clock	Small

Note: Decreasing the aperture size improves the image quality, but darkens the image.

4. Gradually turn the BRIGHTNESS knob (L1-14) clockwise. If the illumination spot center deviates from the screen center (Fig. 5.2-16a), return the spot to the screen center by manipulating knobs 2 and 3.
5. Manipulate knobs 2 and 3 so that the illumination spot concentrically converges on and spreads from the screen center (Fig. 5.2-16b) when the BRIGHTNESS knob (L1-14) is turned clockwise and counterclockwise around the position for the smallest illumination spot.



a: Incorrectly aligned



b: Correctly aligned

Fig. 5.2-16 Condenser lens aperture alignment

5.2.6 Specimen holder insertion

1. Carry out the following check:

 1a. Let the CRT display PAGE-3 (see Sect. 5.2.11a) and confirm that valve V7 is closed.

 1b. Confirm that the X-tilt angle is 0°. If the X-tilt angle is not 0°, zero it with the applicable X pedal switch (Fig. 5.2-17).

 Note: The X-tilt speed can be varied with the X-TILT knob (L1-18).

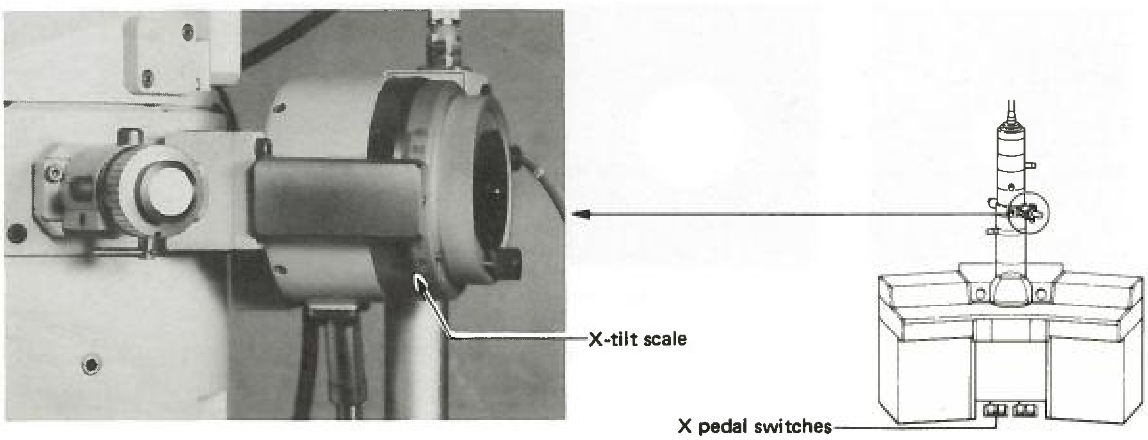


Fig. 5.2-17 X-tilt scale

2. Set the two X-tilt angle limiting screws (Fig. 5.2-18) to 25°.

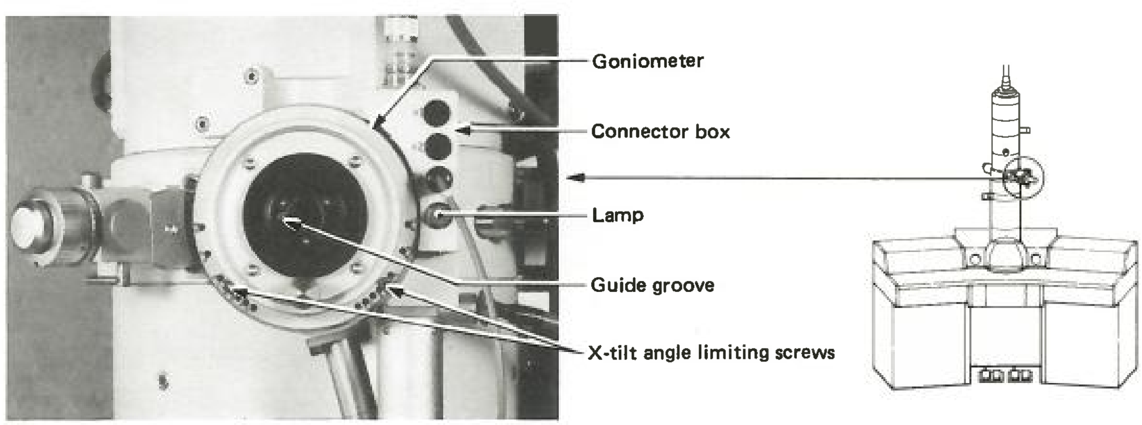


Fig. 5.2-18 Goniometer

3. Remove the protector from the EM-SQH specimen holder loaded with a specimen (see Sect. 5.2.3) and confirm that there is no dirt or lint on the O-ring of the specimen holder.

4. After setting the FILAMENT knob (L1-2) to OFF, match the guide pin of the specimen holder with the guide groove of the goniometer (Fig. 5.2-18), insert the holder into the goniometer until it stops, and wait until the connector box lamp lights up with the holder pushed against the goniometer. Then release your hold, and evacuation of the goniometer starts.

   Note: If valves V2 and V3 are closed and/or the reading of PiG4 is approximately over 150µA with valve V13 open, the connector box lamp does not light up. In such case, wait until valves V2 and V3 open and/or the reading of PiG4 becomes approximately below 150µA. The vacuum system diagram is displayed on PAGE-3 on the CRT.

5. When the connector box lamp goes out (goniometer evacuation is completed), turn the specimen holder clockwise and push it in all the way.
6. Turn the FILAMENT knob (L1-2) to the stopper position.
7. Set the specimen number indicator to the desired specimen number (see Step 5, Sect. 5.2.3) with the specimen selector.

   7a. Let the CRT display PAGE-1 (see Sect. 5.2.11a).

   7b. Depress the LOW MAG button (R1-8) and set the L MAG value on the CRT to 50 to 80 with the SELECTOR switch (R1-9).

   7c. Depress the SP PO key (KB-1) and set the P-Y value on the CRT to 0 with the right specimen shifting knob.

   7d. Spread the electron beam with the BRIGHTNESS knob (L1-14) so that the field of view is entirely covered by the electron beam.

   7e. Set the P-X value on the CRT to +1000 with the left specimen shifting knob.

   7f. Set the specimen number indicator from 1 to 2 and bring the upper right edge of the selected specimen field to the screen center (Fig. 5.2-20) with the specimen selector (Fig. 5.2-19).

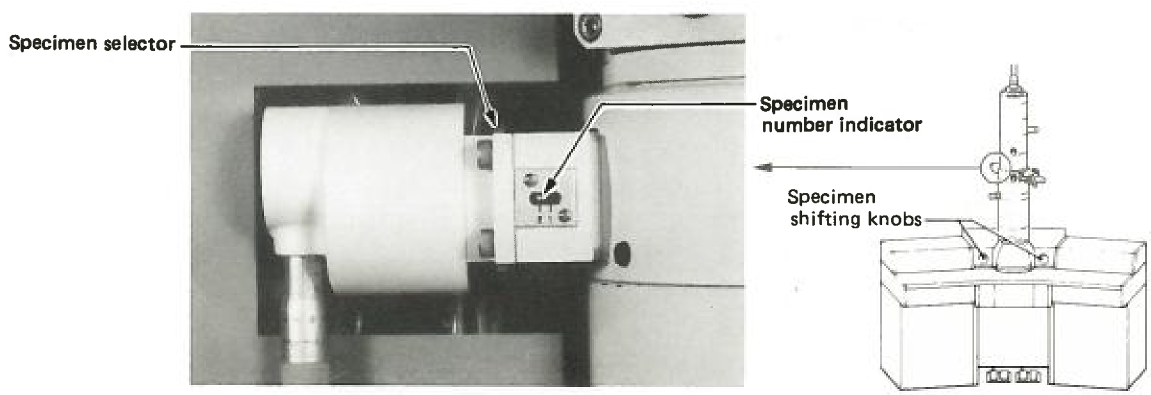


Fig. 5.2-19 Specimen selecting device

8. Select the desired field of view with the left and right specimen shifting knobs.

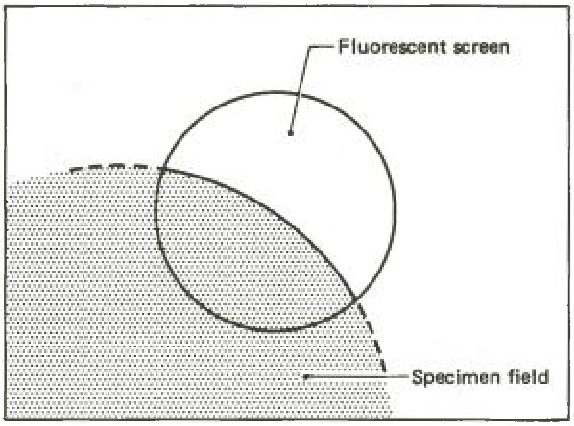


Fig. 5.2-20 Adjusting the field of view

9. Raise the magnification with the SELECTOR switch (R1-9). If this causes the image to darken, adjust the image brightness with the BRIGHTNESS knob (L1-14) and if this causes the selected field of view to shift from the screen center, adjust the field of view with the specimen shifting knobs. When the maximum magnification is obtained, depress the MAG 2 button (R1-8).
10. To remove the specimen holder, proceed as follows:
   10a. Set the FILAMENT knob (L1-2) to OFF.
   10b. Pull the specimen holder, turn it counterclockwise, and draw it out.
   10c. Cover the specimen holder with the protector and place the holder in the specimen holder box.

5.2.7 Inserting the objective lens aperture into the beam path

1. After confirming that the specimen is inserted in the beam path and the MAG2 button (R1-8) is depressed, depress the DIFF button (R1-8). Keep the electron beam sufficiently spread with the BRIGHTNESS knob (L1-14).
2. Obtain a caustic spot (zero magnification spot) with the DIFF FOCUS knob (R1-10) as shown in Fig. 5.2-21. If the caustic spot is off the screen center, center the spot with the PROJ ALIGN: X and Y knobs (R2-3).

Fig. 5.2-21 Caustic spot

3. Obtain the smallest illumination spot with the BRIGHTNESS knob (L1-14) and make the illumination spot center coincide with the caustic spot center by manipulating the SHIFT knobs (L1-16, R1-1).
4. Set the objective lens aperture assembly lever to the left side (Fig. 5.2-22).

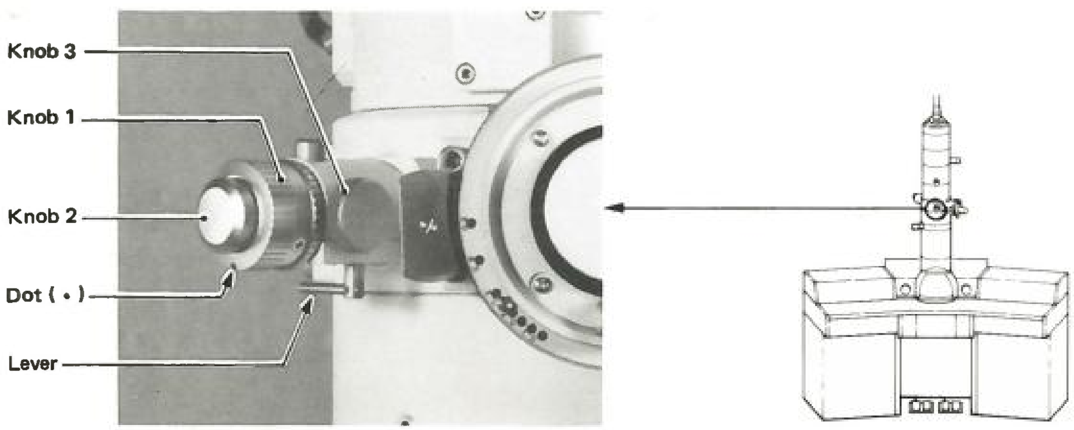


Fig. 5.2-22 Objective lens aperture assembly

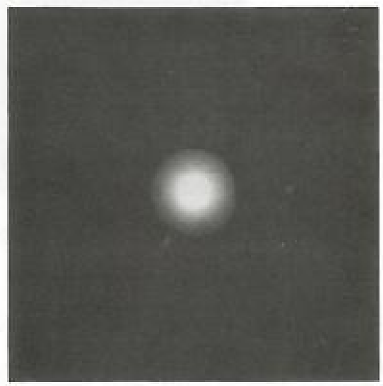
5. Select the desired aperture size with knob 1. The relation between the aperture size and the position of the dot (•) on knob 1 is as follows:

Dot position	Aperture size
6 o'clock	Large
Half past 7	Medium
9 o'clock	Small

Note: Decreasing the aperture size improves the image quality, but darkens the image.

6. Focus the aperture image (shadow) with the DIFF FOCUS knob (R1-10).
7. Manipulate knobs 2 and 3 so that the caustic spot lies in the center of the aperture hole image as shown in Fig. 5.2-23.

Incorrectly aligned



Correctly aligned

Fig. 5.2-23 Objective lens aperture alignment

8. Depress the MAG2 button (R1-8).

5.2.8 Image observation

1. After confirming that the MAG2 button (R1-8) is depressed, obtain the smallest illumination spot with the BRIGHTNESS knob (L1-14), and bring the spot to the screen center with the SHIFT knobs (L1-16, R1-1).
2. Depress the IMAGE X (or Y) button (R1-4). If the illumination spot appears as a double spot or divides into two spots, adjust the IW ADJ: X (or Y) knobs (R2-2) so as to obtain a single illumination spot.
3. Spread the illumination spot with the BRIGHTNESS knob (L1-14). If the image is doubled, adjust the OBJ FOCUS knobs (R1-3) so as to obtain a single stationary image. Then, release the IMAGE X (or Y) button (R1-4).

   Note: When the OBJ 16X button switch (R1-3) is on, the objective lens current variable range enlarges 16 times.

4. Select the desired field of view with the left and right specimen shifting knobs.

   Note: The selected field of view is indicated by the ■ mark on PAGE-2 on the CRT (see Sect. 5.2.11a).

5. Let the CRT display PAGE-1 and confirm that the name of the objective lens pole piece being used is displayed on PAGE-1. If the displayed name is different from that of the pole piece being used, repeatedly depress the MAG key (KB-1) until the same pole piece name is displayed.

   Caution: If the objective lens pole piece name displayed on PAGE-1 is different from the name of the pole piece being used, the correct magnification is not displayed.

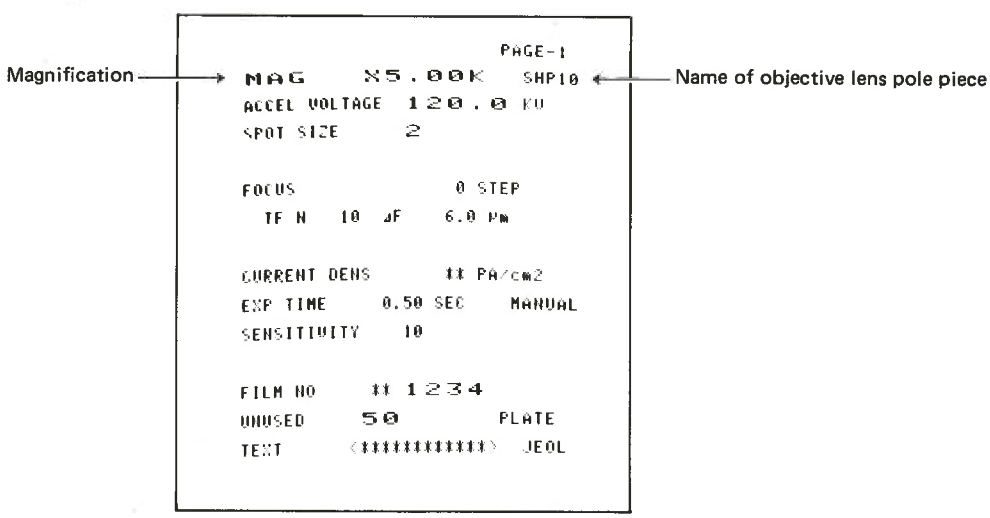


Fig. 5.2-24 PAGE-1

6. Select the desired magnification with the SELECTOR switch (R1-9) (a suitable magnification: less than 50,000X) and adjust the image brightness with the BRIGHTNESS knob (L1-14). If the illumination spot

center does not coincide with the screen center, center the illumination spot with the **SHIFT** knobs (L1-16, R1-1).

Note: If a magnification is selected with the MAG2 button (R1-8) depressed, the selected magnification is not stored in the memory. However, if a magnification is selected with the MAG1 button (R1-8) depressed, the selected magnification is stored in the memory. That is to say, the magnification is automatically set to the stored value by depressing the MAG1 button. On the other hand, by depressing the MAG2 button, the magnification is always set to 5,000X.

7. Depress the IMAGE X (or Y) button (R1-4). If the image appears as a double image, adjust the OBJ FOCUS knobs (R1-3) so as to obtain a single stationary image (focusing using the image wobbler). Then release the depressed button.

5.2.9 Image recording by automatic exposure

1. Turn on the SHUTTER AUTO button switch (R1-6) and turn off the FILM ADVANCE AUTO button switch (R1-7).
2. Bring the field of view to be photographed into the frame (⌜ ⌝) on the fluorescent screen with the left and right specimen shifting knobs as shown in Fig. 5.2-25.

   Note: A large frame and a small frame are drawn on the fluorescent screen. The large frame is used for photography using special films.

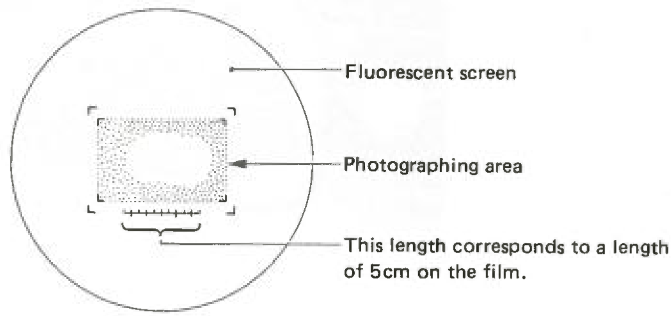


Fig. 5.2-25 Photographing area

3. If the position of the field of view is to be stored, carry out the steps in Sect. 5.2.11i.
4. Write the information to be recorded on the film on PAGE-1. 2 characters can be written on the FILM NO line and 12 characters on the TEXT line (Fig. 5.2-26). See Sects. 5.2.11g and j for details.

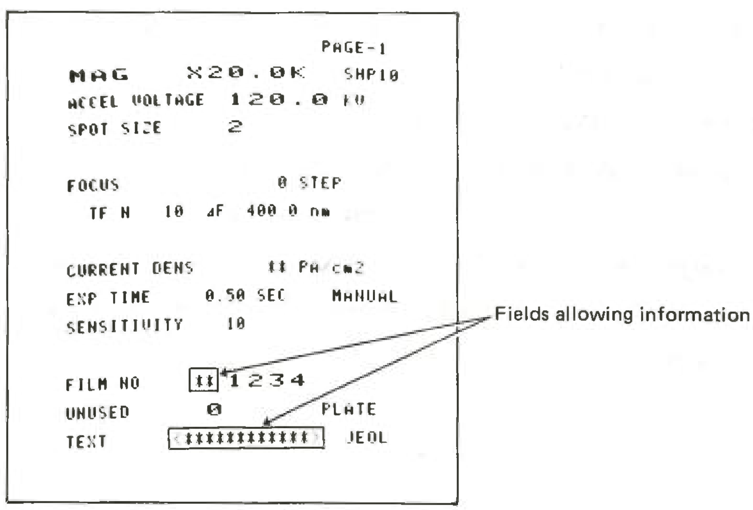


Fig. 5.2-26 Fields allowing information to be written

5. Focus the image.

5a. Pull the fluorescent screen lever (Fig. 5.2-27) until it stops. The small fluorescent screen is now inserted into the beam path.

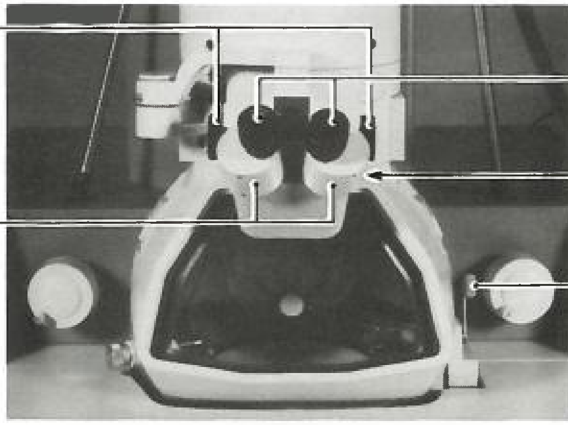


Fig. 5.2-27 Binoculars

5b. Focus the binoculars on the small fluorescent screen.

Note: First, focus the whole binoculars with the focusing knobs, and adjust, if necessary, the inter-ocular distance by changing the distance between the bodytubes, and focus the eyepieces by turning the knurled ring (Fig. 5.2-27).

5c. Depress the OUF button (L1-10).

Note: By using this switch in conjunction with the image wobbler, an optimum underfocus image can be easily obtained. The amount of underfocus can be varied by keyboard operation (see Sect. 5.2.11o).

5d. Depress the IMAGE X (or Y) button (R1-4). If the illumination spot oscillates or divides into two spots, adjust the IW ADJ: X (or Y) knobs (R2-2) so as to obtain a single stable illumination spot.

5e. Observe an image with clear contours on the small fluorescent screen through the binoculars. If the image appears as a double image, adjust the OBJ FOCUS knobs (R1-3) so as to obtain a single stationary image. If the image is underfocused or overfocused, it will appear as a double image as shown in Fig. 5.2-28.

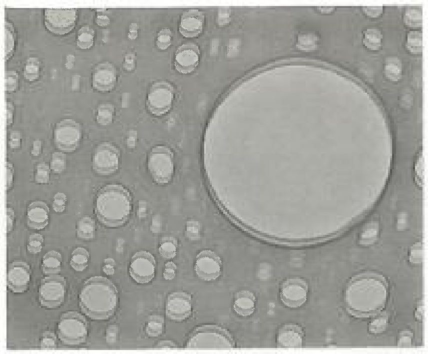
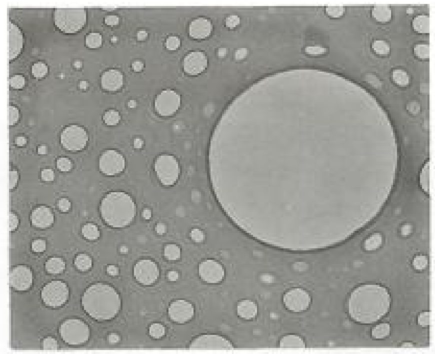
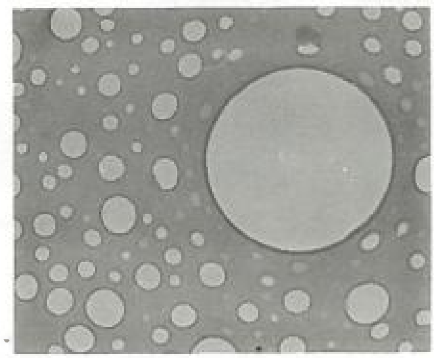
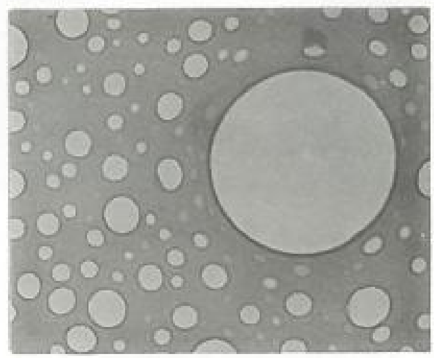
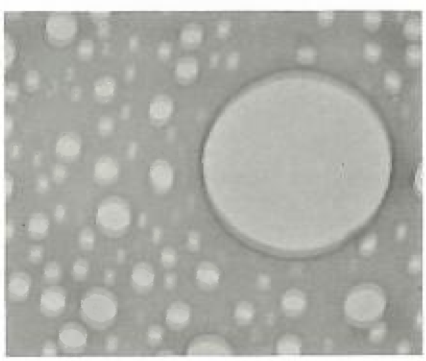
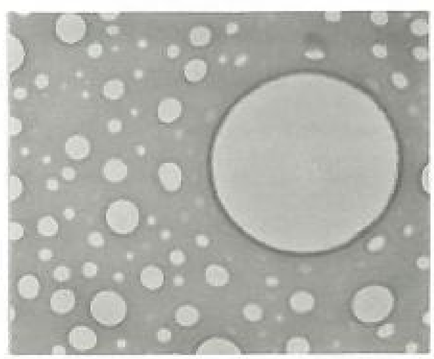
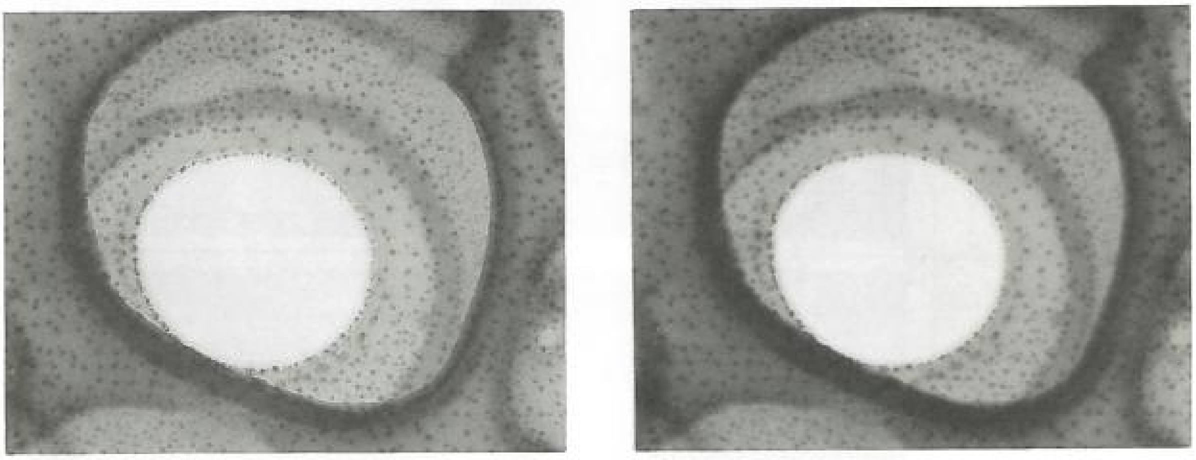
	IMAGE X button switch	
	ON	OFF
Underfocus		
In-focus		
Overfocus		

Fig. 5.2-28 Focusing with the image wobbler

5f. Release the IMAGE X (or Y) button switch (R1-4).

In this state (with the IMAGE X (or Y) button switch (R1-4) off after focusing with the OUF button switch (L1-10) and IMAGE X (or Y) button switch on), an optimum underfocus image can be photographed (Fig. 5.2-29).



a: **Optimum underfocus** b: **In-focus**

Fig. 5-2-29 Optimum underfocus

6. Adjust the image brightness.

6a. Let the CRT display PAGE-1.

6b. Adjust the BRIGHTNESS knob (L1-14) so that the exposure time displayed on the EXP TIME line becomes the desired value (usually 2 to 4 sec).

Note: If the relation between the brightness and the exposure time is to be changed, carry out the steps in Sect. 5.2.11 ℓ.

7. Depress the PHOTO button (L1-12) with the small screen in the beam path, and after the built-in lamp of the button lights up, depress the PHOTO button again. If the built-in lamp is already on, depress the PHOTO button only once.

Notes: 1. The EXP lamp (L1-13) lights up and remains lit while the shutter is open. The built-in lamp of the PHOTO button (L1-12) goes out when the exposed film is advanced from the exposing position.

2. The PHOTO button lamp does not light when all loaded films have been exposed.

3. When the large screen is entirely illuminated, the small screen may be retracted from the beam path.

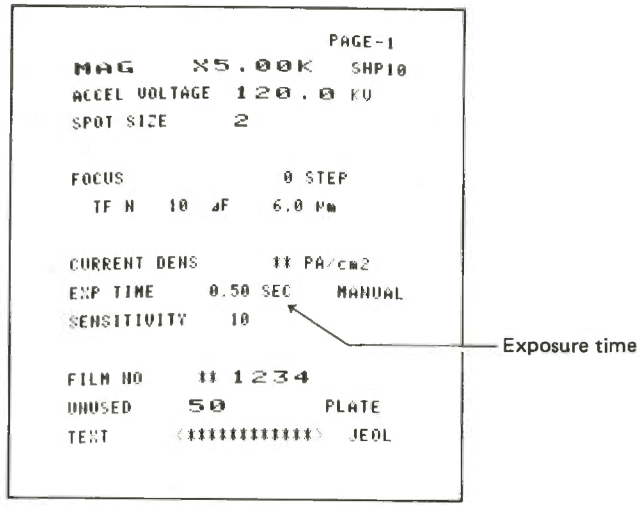


Fig. 5.2-30 Exposure time

5.2.10 Film processing

1. Unload the receiving magazine from the camera chamber (see Sect. 5.2.2b).
2. Adjourn to a darkroom and remove the lid from the receiving magazine and the cassettes from the magazine under a safelight (red lamp).
3. Carefully remove the film from the cassette (Fig. 5.2-31).

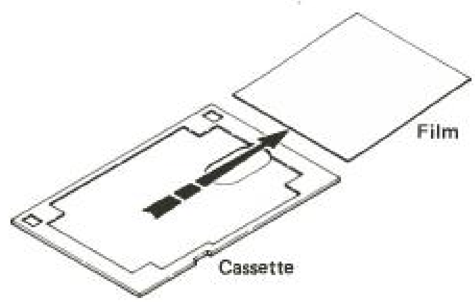


Fig. 5.2-31 Removing the film from the cassette

4. Immerse the film in a developer (20 ± 0.5°C), and leave it in until the exposed latent image becomes sufficiently visible (usually three or four minutes; Fig. 5.2-32).
   During the developing process, agitate the developer or move the film in order to avoid developing marks.
   Note: If only a few films are to be processed, developing trays may be used. However, if many films are to be processed at one time, it is recommended to use suitable tanks and hangers (stainless steel tanks, polyvinyl chloride tanks, etc. are the best).
5. Immerse the film in a stop bath (2 to 3% glacial acetic acid solution, 18 to 21°C) and leave it in for approx. 30 seconds. This is to suspend development so as to prevent the film from becoming blotchy and to prolong the effectiveness of the fixer.
6. Immerse the film in a rapid acid hardening fixer (18 to 21°C) and leave it in for approximately ten minutes (the fixing time should be at least two or three times the time it takes for the negative to clear).
   This is to dissolve the photosensitive silver halide (white part of the film) and thereby make the unexposed part of the film transparent.

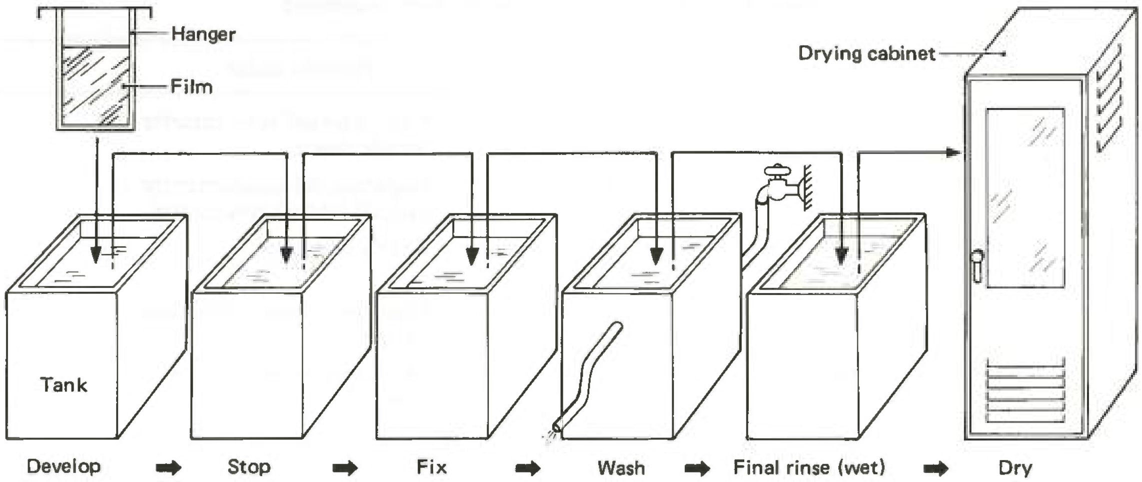


Fig. 5.2-32 Film processing

Thereafter, processing can be carried out under an ordinary light.

7. Wash the film in running water (15 to 20°C) for 30 to 60 minutes.

   This removes the complex salt and fixing solution. The washing time can be considerably reduced by immersing the film in a rinse accelerator prior to washing it in running water.

8. Immerse the film in a final rinse bath (weak solution of anionic surfactant, 18 to 21°C) and leave it in for approx. 30 seconds (or wipe both surfaces of the film carefully with a soft sponge).

   By so doing, film drying time is reduced and film blisters are prevented.

9. Dry the film in a drying cabinet (the cabinet need not be large), or dry it naturally by hanging it in a well-ventilated, dust-free place away from direct sunlight.

   Store the dried film in a negative bag (polyethylene, cellophane, etc.) and keep the bag in a dry place away from direct sunlight.

   Note: Consequences of faulty film processing, etc. are listed in Table 5.2 (assuming that the exposure is in order).

Table 5.2 Consequence of faulty film processing

Appearance	Possible cause
• No picture	Film inserted into cassette upside-down.
• Complete blackening	Magazine lid inadvertently opened while being carried.
• Fogging	Faulty safelight.
	Film processing date has expired.
• High density	Developer temperature too high.
• Low density	Developer temperature too low.
• Too grainy	Developing time too long.
• Uneven density	Developing time too short.
	Effete developer.
• Spotty staining (mottled)	Developer agitation insufficient.
	Film electrostatically charged before developing.
• Scratches, streaks	Film emulsion surface abrased.
• Discoloration of film during storage	Fixing and rinsing insufficient.
• Moldy film	Method and place of storage unsuitable.
	Drying insufficient.
• Extraneous particulates	Impurities in tap water.
• Blisters on film	Water droplets left on film before drying.
• Reticulation	Tap water temperature too high.

5.2.11 Keyboard operation

5.2.11a Page change

The page displayed on the CRT can be changed in two ways, as follows:

- By using the command keys (KB-1)

  PAGE-1 to PAGE-8 are displayed one after another by depressing the PAGE key.

- By using the standard keys (KB-2)

1. When PAGE-1 or PAGE-2 is displayed on the CRT, make sure that no character is displayed on the bottom margin of the PAGE. If any character is displayed, change the PAGE by using the PAGE key (KB-1). When PAGE-7 is displayed, make sure that there is no cursor (■ mark) on the PAGE. If a cursor is on the PAGE, change the PAGE by using the PAGE key (KB-1).
2. Depress | P | G | the desired page number (1 to 8) | RETURN |.

   If "ERROR" appears in the bottom margin, carry out this step once again.

The contents of each page (8 pages in all) are found in Subsect. 4.2.6. CRT brightness can be adjusted with the CRT INTENSITY knob (R1-13).

5.2.11b ALIGN display

The alignment procedures are sequentially displayed on the CRT (see Subsect. 5.3).

5.2.11c Recording by printer

By depressing the PRINT key (KB-1), the whole information displayed on the CRT is recorded by the printer (attachment).

5.2.11d PC board check

Whether each PC board is normal is displayed on the CRT when | C | H | E | C | K | RETURN | (KB-2) is depressed.

5.2.11e Changing the name of pole piece (displayed magnification and camera length)

When the objective lens and/or condenser lens pole piece(s) is(are) changed, the following procedure should be carried out so that incorrect magnification and camera length are not displayed on PAGE-1, and lens current, etc. do not become inadequate.

1. Obtain PAGE-1 on the CRT.
2. While keeping the CTRL key (KB-2) depressed, obtain an asterisk on the left upper corner of PAGE-1 (Fig. 5.2-33) with the A key (KB-2).

3. Depress | P | R | = | OL pole piece name | , | CL pole piece name | RETURN |. If "ERROR" appears in the bottom margin, carry out this step once again.

Notes: 1. *An OL pole piece name is selected from among AHP, BLP, SAP, SHP, STP, UHP, etc. Generally SAP or SHP is selected. A CL pole piece name is either S (single-gap) or D (double-gap). S is generally used.*

2. *Although the OL pole piece name is displayed on PAGE-1 (Fig. 5.2-33), the CL pole piece name is not displayed.*

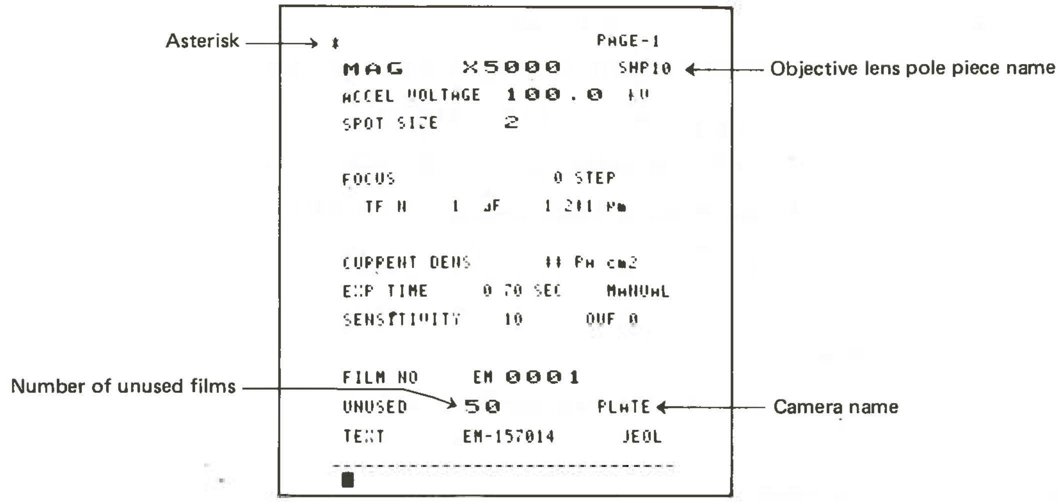


Fig. 5.2-33 PAGE-1

5.2.11f Character writing

- Characters can be written on PAGE-1, 2 and 7, and stored in the memory. When the key of the desired character is depressed, the character is written at the position marked with ■ (cursor) in the bottom margin of PAGE-1 and 2, or on PAGE-7, and at the same time, the ■ mark shifts to the next position.
- To shift the ■ mark left without writing any character, depress the ← key (KB-2) and if the ■ mark is to be shifted right without writing any character, depress the → key (KB-2).
- To erase a character, move the ■ mark to the position of the character to be erased with the ← or → key (KB-2) and then depress the space key (KB-2). If all the characters on PAGE-7 are to be erased, depress the TEXT key (KB-1) three or more times.
- To store the written characters in the memory, depress the RETURN key (KB-2) in the case of PAGE-1 and 2. In the case of PAGE-7, depress the PAGE key (KB-1).
- If (an) inadequate character(s) have (has) been written, "ERROR" appears in the bottom margin of PAGE-1 or 2 when the RETURN key (KB-2) is depressed. In such case, erase "ERROR" by re-displaying the same PAGE with the PAGE key (KB-2), then write (an) adequate character(s).

SP

5.2.11g Writing the TEXT

Any characters not exceeding 12 characters can be written on the TEXT line of PAGE-1. The characters written are printed on the film when photographing.

1. Depress the TEXT key (KB-1). "TEXT" now appears in the bottom margin of PAGE-1 (Fig. 5.2-34).
2. Write the desired characters in the margin (Subsect. 5.2.11f).
3. Depress the RETURN key (KB-2).

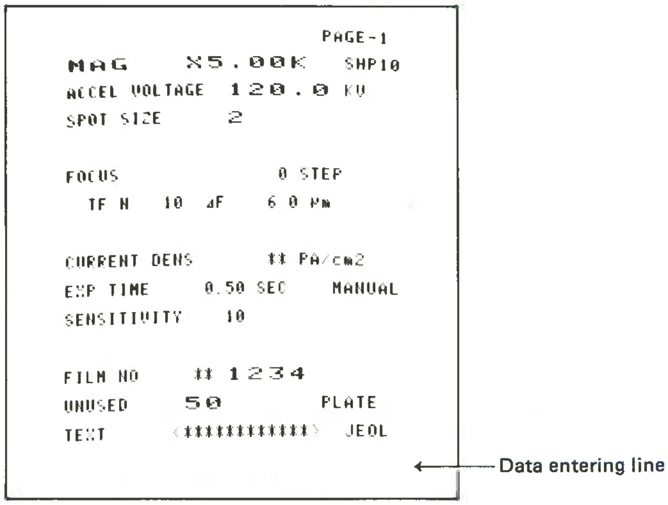


Fig. 5.2-34 TEXT writing

5.2.11h Setting the minimum amount of accelerating voltage change

The accelerating voltage can be changed stepwise with the ACCEL VOLTAGE switch (L1-5). The amount of voltage change per step is set freely (0.03 kV and 0.1 to 20.0 kV) by the following procedure:

1. Obtain PAGE-1 with the PAGE key (KB-1).
2. Depress $\boxed{H}\boxed{T}$. "HT STEP = KV/STEP" appears in the bottom margin of PAGE-1.
3. When the amount of change is to be set to 0.03 kV, depress $\boxed{0}\boxed{0}\boxed{0}\boxed{3}$. When the amount of change is to be set to 0.1, 0.2, . . . or 20 kV, depress $\boxed{0}\boxed{0}\boxed{1}\boxed{0}$, $\boxed{0}\boxed{0}\boxed{2}\boxed{0}$ . . . or $\boxed{2}\boxed{0}\boxed{0}\boxed{0}$.
4. Depress the RETURN key (KB-2). If "ERROR" appears in the bottom margin, start again from Step 2.

5.2.11i Storing in the memory the position of the field of view

The position of the field of view appearing on the fluorescent screen, specimen position in other words, is displayed on PAGE-2 by a coordinate and graph. Up to three specimen positions can be displayed and stored.

1. Obtain PAGE-2 with the PAGE key (KB-1).
2. Depress $\boxed{S}\boxed{P}$. "SPECIMEN POSITION =" appears in the bottom margin of PAGE-2.

3. Depress the 0, 1 or 2 key (KB-2) corresponding to the line number where the current specimen position is to be stored (see Subsect. 5.2.11f).
4. Depress the RETURN key (KB-2). If "ERROR" appears in the bottom margin, start again from Step 2.

When all the specimen positions displayed on PAGE-2 are to be erased, depress 0 (zero) P 0 (ou) S I RETURN .

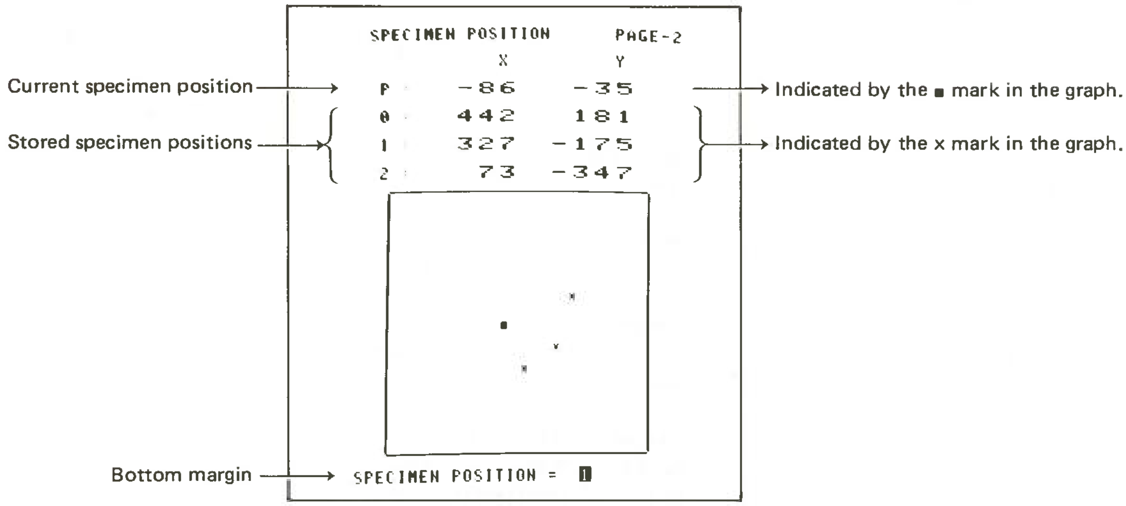


Fig. 5.2-35 PAGE-2

5.2.11j Setting the film number and number of unused films

Of the six characters displayed on the FILM NO line of PAGE-1, the last four are the film number which advances by one every time a film is exposed, but the first two remain unchanged unless rewritten by the operator. The number displayed on the UNUSED line is the number of unused films (Fig. 5.2-33) which is reduced by one every time a film is exposed. The six characters displayed on the FILM NO line are printed on the film at the time of exposure.

1. Depress the F NO key (KB-1). "FILM NO" and "UNUSED" appear in the bottom margin of PAGE-1.
2. Write the desired characters in the bottom margin (see Subsect. 5.2.11f).
3. Depress the RETURN key (KB-2). If "ERROR" appears in the bottom margin, start again from Step 1.

5.2.11k Selecting the camera

When the standard camera is to be used, first obtain PAGE-1 with PAGE key (KB-1), then depress F I L M = P L A T E RETURN . When a 35 mm camera is to be used, depress A 3 5 instead of PLATE. "PLATE" or "A35" appears at the end of UNUSED line.

5.2.11ℓ Setting the exposure index

The exposure time of automatic exposure can be changed by changing the SENSITIVITY number on

PAGE-1 through the keyboard.

1. Obtain PAGE-1 with the PAGE key (KB-1).
2. Depress | S | E | . "FILM SENSITIVITY" appears in the bottom margin of PAGE-1.
3. Write the desired number (1 to 20) in the bottom margin through the keyboard. The larger the number, the shorter the exposure time for the same image brightness.
4. Depress the RETURN key (KB-2).

5.2.11m Storing the lens system condition and setting the lens system to the stored condition

Ten types of lens system can be stored in the memory, or the lens system can be set to any of the stored conditions.

- To store the operating conditions:

1. Obtain PAGE-1 with the PAGE key (KB-1).
2. Depress | U | F | space key | I | N | RETURN | . "U.F. MEMORY IN" appears in the bottom margin of PAGE-1.
3. Select the desired position (number) out of ten (0, 1, . . . 9) storing positions and write it in the bottom margin through the keyboard (see Subsect. 5.2.11f).
4. Depress the RETURN key (KB-2).

- To set the stored operating conditions:

1. Obtain PAGE-1 with the PAGE key (KB-1).
2. Depress | U | F | space key | O | U | T | RETURN | . "U.F. MEMORY OUT" appears in the bottom margin of PAGE-1.
3. Write the number of memory position, where the desired lens system is stored, in the bottom margin through the keyboard.
4. Depress | D, L or space key | RETURN | .

   If all the beam deflector currents (except those for the electron gun beam deflectors, spot alignment coil, intermediate stigmator and projector lens beam deflector) are to be reproduced, the D key (KB-2) should be depressed before the RETURN key is depressed. If all the lens currents are to be reproduced, the L key (KB-2) should be depressed. If the space key is depressed, both the beam deflector currents and lens currents are reproduced.

5.2.11n Setting the through-focus series condition

The number of films to be exposed and the amount of focus change per film can be set (see Subsect. 5.6.3).

5.2.11o Setting the amount of OUF (optimum underfocus)

1. Obtain PAGE-1 with the PAGE key (KB-1).

2. Depress $\boxed{\text{O (ou)}}\boxed{\text{U}}$. "OUF NO =" appears in the bottom margin of PAGE-1.
3. Write 1, 2 or 3 in the margin through the keyboard. If the OUF is not required, write 0 (zero) instead of 1, 2, or 3.

   Note: The amounts of underfocus when 1, 2 or 3 is written are 1-, 2- or 4-times the preset value, when the IMAGE X (or Y) button (R1-4) is depressed. When the IMAGE X and Y buttons are depressed, the amount of underfocus is twice that set up when either IMAGE X (or Y) button is depressed.
4. Depress the RETURN key (KB-2). If "ERROR" appears in the margin, restart from Step 2. When the RETURN key is depressed, the OUF number is displayed on the end of the SENSITIVITY line of PAGE-1.

5.2.11p Setting the mode of minimum exposure operation

Refer to Subsect. 5.6.4.

5.2.11q Using the BRIGHT ZOOM system

The change in image brightness when the magnification is varied is reduced to the minimum by using the BRIGHT ZOOM system.

1. Turn off the BRIGHT ZOOM and BRIGHT 16X switches (L1-10, 11).
2. Turn on the MAG1, MAG2 or SAM/ROCK switch (R1-8).
3. Turn on the SHUTTER AUTO switch (R1-6).
4. Make the electron beam as small as possible with the BRIGHTNESS knob (L1-14), then obtain the desired image brightness by turning the knob clockwise.
5. Turn on the BRIGHT ZOOM switch (L1-10).

   Notes: 1. When the magnification is varied drastically, several seconds may pass before the zooming circuit is in full operation.

   2. When the magnification is too high or too low, weak peep sounds will be heard. Then, start again from Step 1.

   3. Begin from Step 1 when the field of view is changed.

5.2.11r Setting the basic magnification

When the MAG2 button (R1-8) is depressed, the magnification is set to a specified value (basic magnification). The basic magnification, which has been set to 5,000 times, can be changed as follows:

1. Depress the MAG2 button (R1-8) and select the desired magnification.
2. Obtain PAGE-1 with the PAGE key (KB-1).
3. Depress $\boxed{\text{M}}\boxed{\text{A}}\boxed{\text{G}}\boxed{\text{2}}\boxed{\text{RETURN}}$.

5.2.11s Writing USER'S COMMENTS

Obtain PAGE-7 with the PAGE key (KB-1) and write comments referring to Subsect. 5.2.11f.

Notes: 1. *Use the RETURN key (KB-2) to start a new paragraph. To move the ■ mark downwards, use the LINE FEED key (KB-2).*

2. *If the ■ mark does not appear, re-obtain PAGE-7 with the PAGE key (KB-2) to display the mark. No character can be written on PAGE-7 unless the mark has appeared.*

5.2.12 Shutdown procedure

1. Turn the FILAMENT knob (L1-2) to OFF and depress the HT button (L1-6) to turn off the accelerating voltage.
2. Remove the specimen holder (pull, turn counterclockwise, and draw out), cover the holder with the protector, and store the holder in the specimen holder box (Fig. 5.2-7).
3. Set the POWER switch (L1-3) to OFF, and wait 5 to 10 minutes.
4. After the microscope has completely shut down, close the cooling water faucet and turn off the main power switch on the distribution board.

5.2.13 Data printout on micrograph (Fig. 5.2-36)

a. Specimen name, etc.: Entered from the keyboard (not more than 12 characters).

b. Micron bar: The calibrated length of the bar corresponds to the length on the specimen.

c. Film number: Six digits (the last four digits indicate the film number and the first two are optionally entered for other identification).

d. Accelerating voltage

e. Magnification or camera length

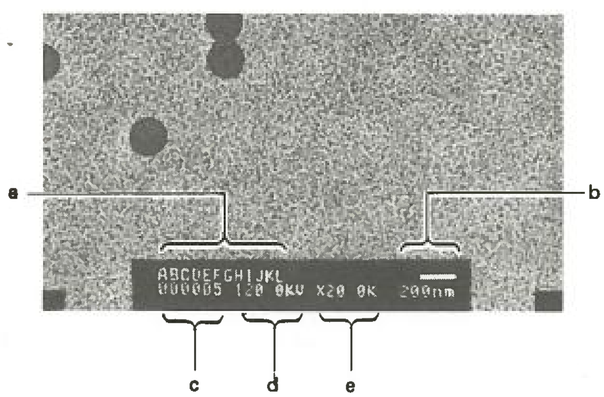


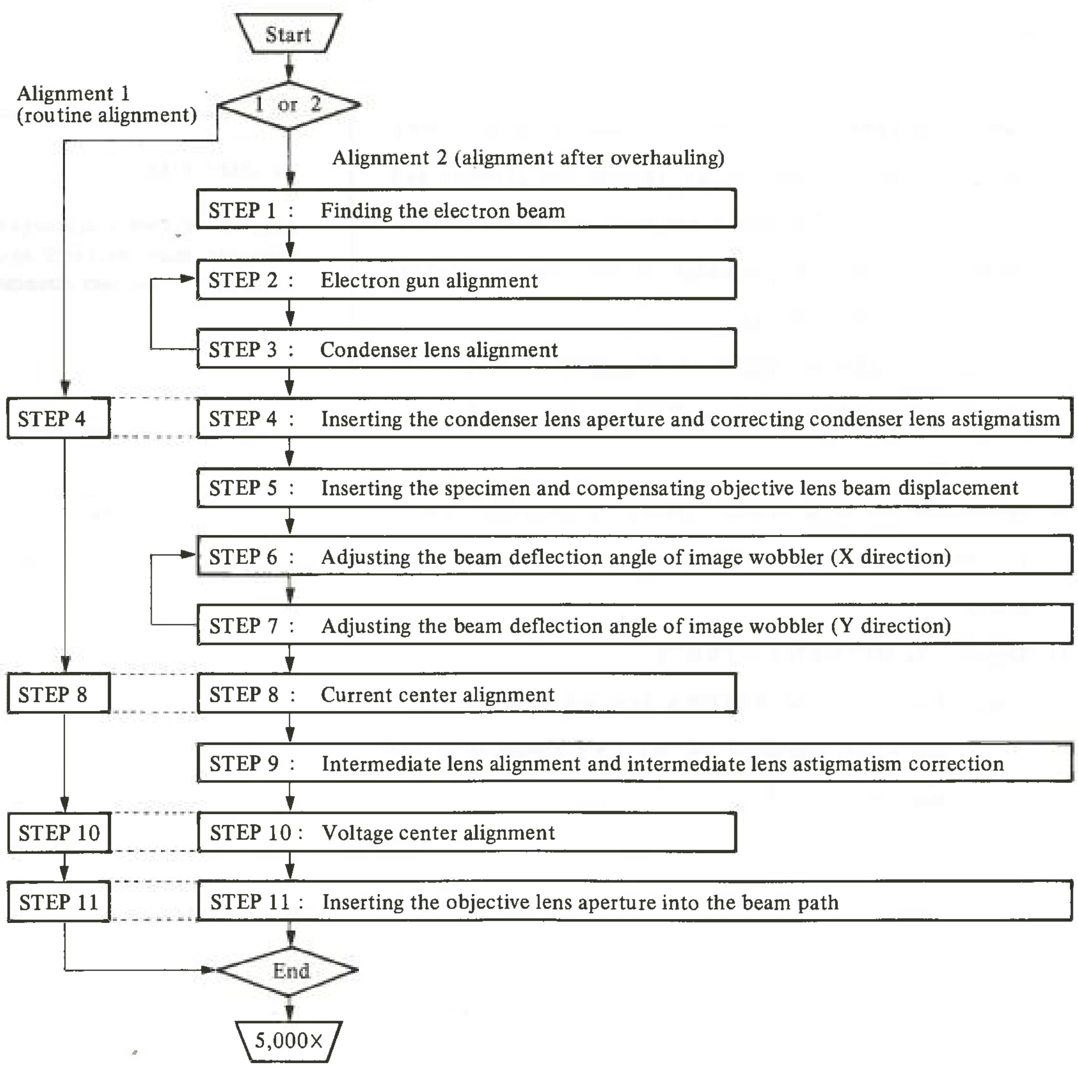
Fig. 5.2-36 Data printout on micrograph

5.3 Method B

This section covers the column alignment procedure required when the microscope conditions are unknown after overhauling or pole piece replacement. Procedures detailed in method A are skeletonized in this section. Practice method A (Sect. 5.2) repeatedly before attempting method B. See method C (Sect. 5.4) for routine operation.

5.3.1 CRT display

Two methods of column alignment, 1 (routine alignment) and 2 (alignment after overhauling), can be displayed on the CRT. Alignment 1 is for method C, and alignment 2 for method B. The alignment procedure is divided into 11 steps, which are sequentially displayed on the CRT.



5.3.2 Column alignment

1. Obtain PAGE-1 with the PAGE key (KB-1), make sure that an asterisk (see Fig. 5.2-33) has not been displayed on PAGE-1, then depress [A][L][I][G][N][RETURN]. "COLUMN ALIGNMENT" appears on the CRT.

   Notes: *1. If an asterisk is seen on PAGE-1, erase it with the A key (KB-2) while depressing the CTRL key (KB-2).*

   2. While the system is in the ALIGN mode, no other mode can be used. If another mode is required, depress the ESC key (KB-2), wait until PAGE-1 appears, then change the mode.

```
COLUMN ALIGNMENT

1 ROUTINE ALIGNMENT-1
2 COMPLETE ALIGNMENT-2

  HIT  1 OR 2
```

2. Carry out the operation displayed on the CRT, i.e., in this case, depress the 2 key (KB-2). "STEP-1" is now displayed on the CRT.

3. Carryout the STEP-1 operation (as displayed on the CRT).

   3a. Apply the accelerating voltage, remove the aperture and specimen from the electron beam path, and turn the FILAMENT knob (L1-2) clockwise to the stopper position (Steps 1 to 9, Sect. 5.2.4).

   3b. Set the GUN ALIGN: SHIFT: X, Y and TILT: X, Y knobs (R2-1) at the midway position. These knobs are of the five-turn type.

   3c. Manipulate the GUN ALIGN: SHIFT: Y knob (R2-1) so as to obtain the brightest illumination on the fluorescent screen.

   3d. Depress the RETURN key (KB-2).

   Note: *Every time the RETURN key (KB-2) is depressed, the STEP displayed on the CRT advances to the next one.*

```
** STEP- 1 **

REMOVE SPECIMEN & ALL APERTURES
GENERATE BEAM  MAXIMIZE BEAM
INTENSITY USING GUN SHIFT-Y



  LENS OFF  GUN-WOBBLER

       NEXT     HIT RET
```

4. Carry out STEP-2 operation.

   4a. While centering the illumination spot on the fluorescent screen (if the screen is not illuminated by the electron beam, slowly turn the BRIGHTNESS knob (L1-14) to obtain the illumination spot) with the GUN ALIGN: SHIFT knobs (R2-1), manipulate the BRIGHTNESS knob (L1-14) so as to obtain the smallest illumination spot. If the illumination darkens in the course of this operation, brighten it with the GUN ALIGN: TILT knobs (R2-1).

   4b. Manipulate the GUN ALIGN: TILT knobs (R2-1) so as to obtain the brightest illumination spot.

   4c. Depress the RETURN key (KB-2).

5. Carry out the STEP-3 operation.

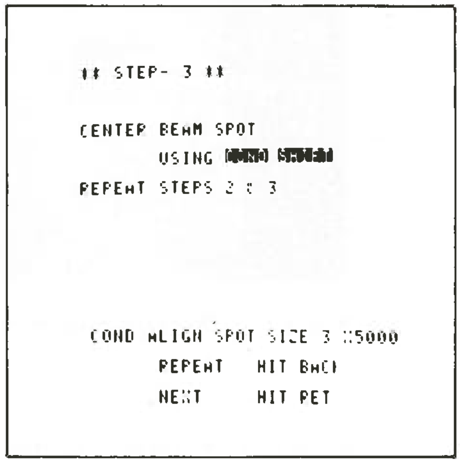
   5a. Bring the illumination spot (if the fluorescent screen is not illuminated with the electron beam, slowly turn the BRIGHTNESS knob (L1-14) to obtain the illumination spot) to the screen center with the SHIFT: X and Y knobs (L1-16, R1-1), and converge the beam with the BRIGHTNESS knob (L1-14).

   5b. Depress the BACK SPACE key (KB-2), and carry out the STEP-2 operation.

   5c. Carry out the STEP-3 operation.

   5d. Repeat STEP-2 and STEP-3 until the illumination spot deviation from the screen center becomes zero in both STEPs.

   5e. Depress the RETURN key (KB-2) in order to make the CRT display STEP-4.



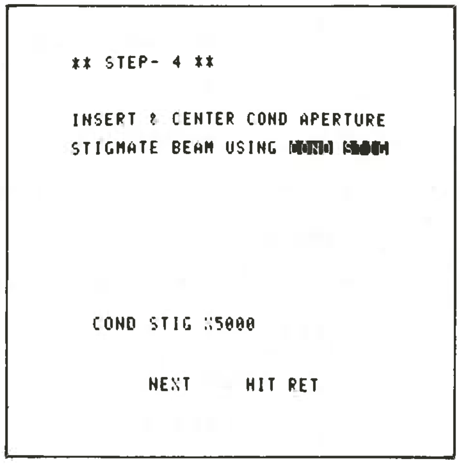
6. Carry out the STEP-4 operation.

   6a. Correct condenser lens astigmatism (circularize the illumination spot) with the DEF: X and Y knobs (L1-17, R1-2).

   6b. Insert the condenser lens aperture into the beam path.

   6c. Correct the condenser lens astigmatism again.

   6d. Depress the RETURN key (KB-2).



7. Carry out the STEP-5 operation.
   7a. Insert the specimen into the electron beam path. If the specimen X-tilt angle is not 0°, set it to 0° (see Sect. 5.2.6).
   7b. Manipulate the SHIFT: X and Y knobs (L1-16, R1-1) and beam displacement compensating knobs (Fig. 5.3-1) so as to minimize the misalignment between the electron beam and specimen.
   7c. Depress the RETURN key (KB-2).

```
** STEP- 5 **

INSERT SPECIMEN  COMPENSATE
BEAM SHIFT USING
        BEAM COMP : COND SHIFT

 BEAM COMP X5000

       NEXT    HIT RET
```

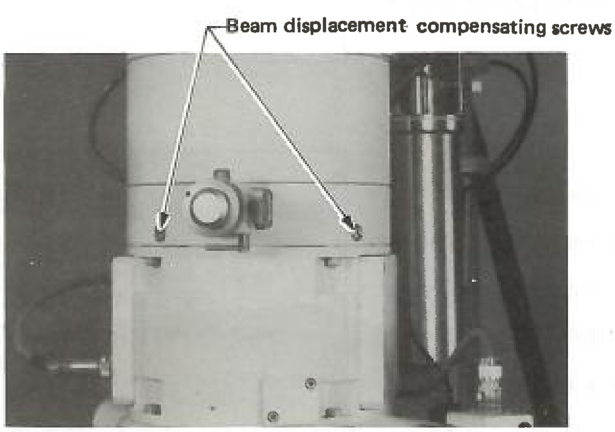


Fig. 5.3-1 Beam displacement compensating screws

8. Carry out the STEP-6 operation.
   8a. Manipulate the IMAGE WOBBLER ADJ: X knobs (R2-2) so that the two separate illumination spots become a single stable spot.
   8b. Depress the RETURN key (KB-2).

```
** STEP- 6 **

BRING TWO BEAM TOGETHER
        USING [illegible]

 IMAGE WOBBLER X X5000

      NEXT    HIT RET
```

9. Carry out the STEP-7 operation.
   9a. Manipulate the IMAGE WOBBLER ADJ: Y knobs (R2-2) so that the two separate illumination spots become a single stable spot.
   9b. Depress the BACK SPACE key (KB-2) and carry out STEP-STEP-6.
   9c. Repeat STEP-6 and 7 until the two spots become one.
   9d. Depress the RETURN key (KB-2).

```
** STEP- 7 **

DO THE SAME USING [illegible]

REPEAT STEPS 6 & 7

 IMAGE WOBBLER Y X5000
      REPEAT   HIT BACK
      NEXT     HIT RET
```

10. Carry out the STEP-8 operation.
    - 10a. Manipulate the BRIGHTNESS knob (L1-14) and spread the illumination spot so that it covers the whole fluorescent screen.
    - 10b. Bring the current center to the screen center with the DIF: X and Y knobs (L1-17, R1-2).

      Note: In STEP-8 (the objective lens current varies periodically), the image rotates around a point. This point is referred to as the current center.
    - 10c. Depress the RETURN key (KB-2).

```
** STEP- 8 **

CORRECT CURRENT CENTER
    USING [illegible] [illegible]



  OBJ WOBBLEP X5000

      NEXT     HIT PET
```

11. Carry out the STEP-9 operation.
    - 11a. Spread the illumination spot with the BRIGHTNESS knob (L1-14), and center the caustic spot with the PROJ ALIGN knobs (R2-3).
    - 11b. Correct intermediate lens astigmatism (that is, circularize the causitc spot) with the INT STG knobs (R2-4).
    - 11c. Depress the RETURN key (KB-2) in order to make the CRT display STEP-10.

```
** STEP- 9 **

DO THE SAME
    USING [illegible] [illegible] [illegible]
AND STIGMATE USING[illegible] [illegible]



  DIFF 250 0cm

      NEXT     HIT PET
```

12. Carry out the STEP-10 operation.
    - 12a. Manipulate the BRIGHTNESS knob (L1-14) and spread the illumination spot so that it covers the whole fluorescent screen.
    - 12b. Bring the voltage center to the screen center with the DEF: X and Y knobs (L1-17, R1-2).

      Note: In STEP-10 (the accelerating voltage varies periodically), the image expands and contrasts alternately about a point. This point is referred to as the voltage center.
    - 12c. Depress the RETURN key (KB-2).

```
** STEP-10 **

CORRECT VOLTAGE CENTER
USING [illegible] [illegible]



  HT WOBBLEP    X25k

      NEXT     HIT PET
```

13. Carry out the STEP-11 operation.

13a. Insert the objective lens aperture into the electron beam path.

A clear image of the aperture can be obtained by manipulating the DIFF FOCUS knob (R1-10).

13b. Depress the RETURN key (KB-2), and wait for PAGE-1 to be displayed on the CRT.

```
** STEP-11 **

INSERT & CENTER OBJ APERTURE




 DIFF  60 0cm

     NEXT     HIT RET
```

5.4 Method C

This section covers the routine operation of the microscope. Practice method A (Sect. 5.2) repeatedly before attempting method C. If a high resolution image is to be obtained, see also Section 5.5. If the illumination spot disappears from the fluorescent screen in the course of the operation in method C, carry out the operation in method B (Sect. 5.3).

5.4.1 Column alignment

1. Apply the accelerating voltage, remove the apertures and specimen from the electron beam path, and turn the FILAMENT knob (L1-2) clockwise to the stopper position (Steps 1 to 9, Sect. 5.2.4).
2. Obtain PAGE-1 with the PAGE key (KB-1), make sure that an asterisk (see Fig. 5.2-33) has not been displayed on PAGE-1, then depress | A | L | I | G | N | RETURN | . "COLUMN ALIGNMENT" appears on the CRT.

```
COLUMN ALIGNMENT

1 ROUTINE ALIGNMENT-1
2 COMPLETE ALIGNMENT-2

 HIT  1 OR 2
```

   Notes: *1. If an asterisk is seen on PAGE-1, erase it with the A key (KB-2) while depressing the CTRL key (KB-2).*

   2. While the system is in the ALIGN mode, no other mode can be used. If another mode is required, depress the ESC key (KB-2), wait until PAGE-1 appears, then change the mode.
3. Carry out the operation displayed on the CRT, i.e., in this case, depress the 1 key (KB-2).
4. Carry out the STEP-4 operation.

   4a. Correct condenser lens astigmatism (circularize the illumination spot) with the DEF: X and Y knobs (L1-17, R1-2).

   4b. Insert the condenser lens aperture into the electron beam path.

   4c. Correct condenser lens astigmatism again.

   4d. Depress the RETURN key (KB-2).

```
** STEP- 4 **

INSERT & CENTER COND APERTURE
STIGMATE BEAM USING [illegible] [illegible]



 COND STIG X5000

      NEXT     HIT RET
```

5. Carry out the STEP-8 operation.

5a. Manipulate the BRIGHTNESS knob (L1-14) and spread the illumination spot so that it covers the whole fluorescent screen.

5b. Insert the specimen into the beam path and bring the current center to the screen center with the DEF: X and Y knobs (L1-17, R1-2).

Note: In STEP-8 (the objective lens current varies periodically), the image rotates around a point. This point is referred to as the current center.

5c. Depress the RETURN key (KB-2).

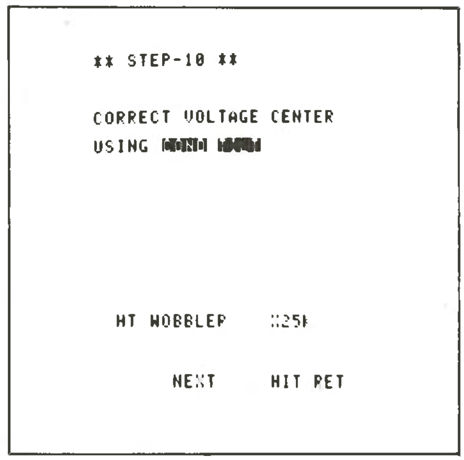
6. Carry out the STEP-10 operation.

6a. Manipulate the BRIGHTNESS knob (L1-14) and spread the illumination spot so that it covers the whole fluorescent screen.

6b. Bring the voltage center to the screen center with the DEF: X and Y knobs (L1-17, R1-2).

Note: In STEP-10 (the accelerating voltage varies periodically), the image expands and contracts alternately about a point. This point is referred to as the voltage center.

6c. Depress the RETURN key (KB-2).



7. Carry out the STEP-11 operation.

7a. Insert the objective lens aperture into the electron beam path.

A clear image of the aperture can be obtained by manipulating the DIFF FOCUS knob (R1-10).

7b. Depress the RETURN key (KB-2), and wait for PAGE-1 to be displayed on the CRT.

8. Release the BRIGHT TILT button (L1-15).

Note: When the BRIGHT TILT button switch (L1-15) is off, manipulation of the DEF: X and Y knobs (L1-17, R1-2) does not affect the voltage center.

9. Check the filament image.

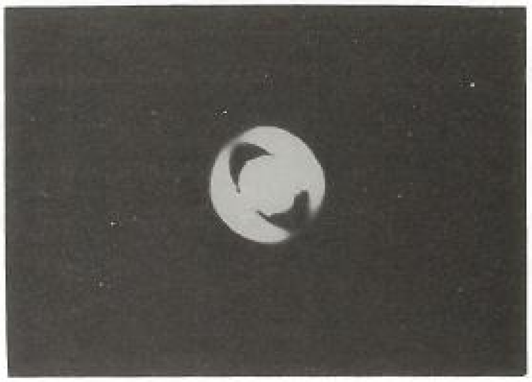
9a. Maximally converge the electron beam with the BRIGHTNESS knob (L1-14).

9b. While observing the illumination spot on the fluorescent screen, gradually turn the FILAMENT knob (L1-2) counterclockwise so as to obtain a filament image (Fig. 5.4-1).

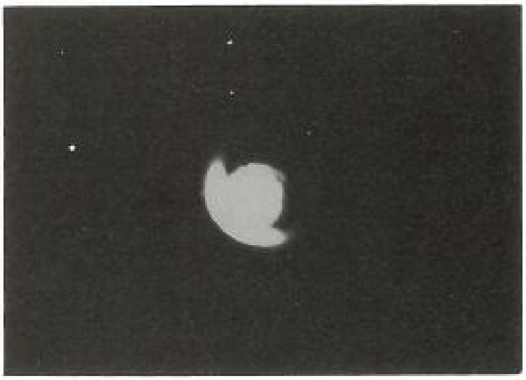
9c. If the filament image is asymmetrical (this indicates that the electron gun is misaligned), make it symmetrical, as shown in Fig. 5.4-1a, with the GUN ALIGN: TILT knobs (R2-1).

9d. Turn the FILAMENT knob (L1-2) clockwise until the filament image disappears (saturation position), and then set the stopper to this position of the knob.

Note: If the FILAMENT knob (L1-2) is set beyond the saturation position, the life of the filament will be considerably shortened. The saturation position changes a little as time passes. Further, it may change when the accelerating voltage or beam current is changed. Therefore, be sure to check the saturation position when the accelerating voltage or beam current is changed.



a: When electron gun is aligned



b: When electron gun is misaligned

Fig. 5.4-1 Filament image

5.4.2 Objective lens astigmatism correction

If astigmatism exists in the objective lens, the focal length differs depending on the beam direction and focusing becomes unidirectional. Therefore, astigmatism must be corrected in order to focus the image in every direction. For astigmatism correction, it is necessary to distinguish between the in-focus and slightly-out-of-focus state of the image. See also the method for focusing with the aid of the Fresnel fringe (Sect. 5.4.3) when correcting objective lens astigmatism.

1. Carry out routine column alignment (Sect. 5.4.1).

   Note: Perforated, thin plastic film reinforced with carbon is recommended as an ideal test specimen for objective lens astigmatism correction. At high magnifications, background structure in the film image (phase contrast) is used for correcting astigmatism (see Sect. 5.5); in which case, specimen supporting film or even a thin specimen without supporting film may well serve the purpose.

2. Obtain a magnification of 5000X, and focus the image using the image wobbler.

   2a. Depress the MAG 2 button (R1-8), and manipulate the BRIGHTNESS knob (L1-14) to spread the illumination spot so that it covers the whole fluorescent screen.

   2b. Depress the IMAGE X or Y button (R1-4).

   2c. Manipulate the OBJ FOCUS knobs (R1-3) to obtain a single stationary image.

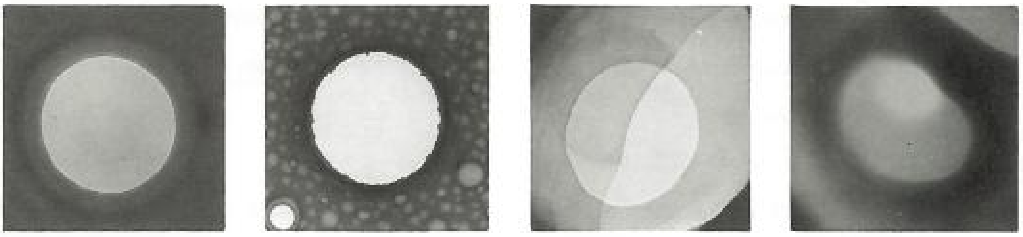
   2d. Release the IMAGE X or Y button (R1-4).

3. Obtain a magnification 1 – 1.5 times the photographing magnification. Adjust the image brightness with the BRIGHTNESS knob (L1-14), and center the illumination with the SHIFT: X and Y knobs (L1-16, R1-1).

4. Insert the small fluorescent screen into the electron beam path, and focus the binoculars on the small fluorescent screen.

5. Select the field of view with the left and right specimen shifting knobs, and bring a hole image of about 5 mm in dia. to the small fluorescent screen.

Note: The test hole used for astigmatism correction should be round and have a smooth circumference as shown in Fig. 5.4-2a. A hole having an uneven circumference, covered by another film, or heavily contaminated by electron beam irradiation, or heavily contaminated by electron beam irradiation, as shown in Fig. 5.4-2b, c, d, is unsuitable.

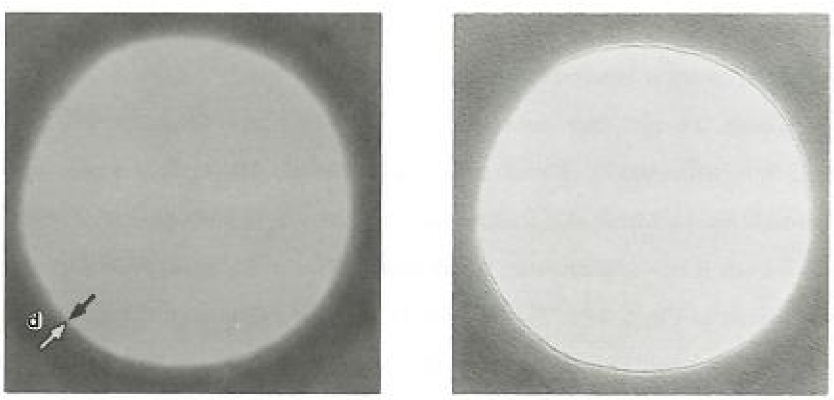


a: Suitable **b: Uneven** **c: Covered by another film** **d: Contaminated**

Unsuitable

Fig. 5.4-2 Test hole for astigmatism correction

6. Depress the OBJ STIG 1 button (L1-15).
7. Slightly overfocus the hole image with the OBJ FOCUS knobs (R1-3) to check astigmatism.
   When the hole image is overfocused, a dark fringe (Fresnel fringe) appears around the edge of the hole; when underfocused, a bright fringe appears around the edge of the hole.
   If the distance (d) between the fringe and the edge of the hole is even all around as shown in Fig. 5.4-3a, there is no astigmatism and the following steps can be omitted. If the distance is uneven as shown in Fig.



a: Fresnel fringe when astigmatism does not exist **b: Fresnel fringe when astigmatism exists**

Fig. 5.4-3 Objective lens astigmatism

5.4-3b, correct the astigmatism as described below.

Note: *If the distance between the fringe and the edge of the hole is too large, it will be difficult to check astigmatism. The distance should be so small that the gap between the fringe and the edge of the hole is just discernible.*

8. Manipulate the DEF: X and Y knobs (L1-17, R1-2) so that the distance between the fringe and the edge of the hole becomes practically uniform.
9. Check astigmatism (Step 7) again. If astigmatism still exists, correct it (Step 8).

   Note: *If the objective lens aperture or the specimen is dirty, or the objective lens aperture is not correctly inserted in the beam path, or the current center is not properly set, it may be impossible to correct astigmatism completely.*
10. Release the OBJ STIG 1 button (L1-15).

    Note: *When the OBJ STIG 1 button switch (L1-15) is off, manipulation of the DEF: X and Y knobs (L1-17, R1-2) does not affect astigmatism.*

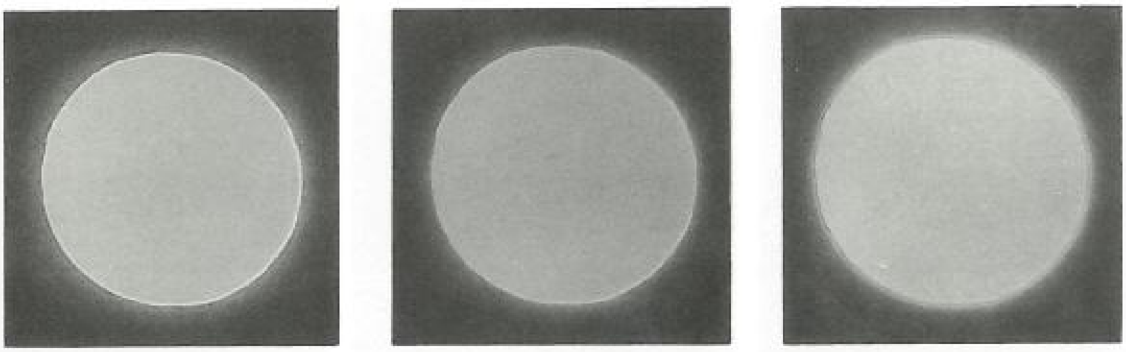
5.4.3 Focusing

This subsection describes how to focus the image using the Fresnel fringe. (The focusing method using the image wobbler is described in Sect. 5.2.) At lower magnifications, focusing using the image wobbler is easier, but at higher magnifications, it is easier to focus with the aid of the Fresnel fringe. See the focusing method utilizing the background structure (Sect. 5.5) for focusing the image at very high magnifications. See also the through-focus method (Sect. 5.6) in which the focus is automatically changed in several steps every time a film is exposed.

1. Manipulate the OBJ FOCUS knobs (R1-3) to obtain the sharpest possible image (coarse focusing).
2. While observing a portion of the image having the greatest contrast (a film hole or dust particle is ideal for practice purpose) through the binoculars, turn the OBJ FOCUS: FINE knob (R1-3) slightly counterclockwise and clockwise, to set it where the image is in-focus.

   If a film hole is used, a bright, high contrast fringe (Fresnel fringe) forms around the edge of the hole, as shown in Fig. 5.4-4a, when the FINE knob is turned counterclockwise. This is referred to as the underfocus condition, a condition in which the contour width increases as the amount of underfocus is increased. When the FINE knob is turned clockwise, a dark fringe (Fresnel fringe) appears slightly apart from the edge of the hole as shown in Fig. 5.4-4c. This is referred to as the overfocus condition, a condition in which the distance between the fringe and the edge of the hole increases as the amount of overfocus is increased. In-focus lies between underfocus and overfocus. As the knob is gradually turned clockwise from the underfocus condition, the width of the bright fringe forming the hole contour decreases. When the fringe dis-

appears and contour contrast is minimum as shown in Fig. 5.4-4b, the image is in-focus (the in-focus image may appear to be somewhat obscure, but it should not be construed that it is out of focus). As the knob is turned further clockwise, the image assumes an ambiguous state and appears as either an in-focus or over-focused image. (This is caused by the fact that the resolving power of the fluorescent screen is less than that of the film. If the image is photographed in this state, an overfocus fringe will be observed.) Immediately after the image has assumed such a state, a dark fringe appears slightly away from the edge of the hole (overfocus) as the knob is turned further clockwise. Fig. 5.4-5 shows this continuous change schematically.



a: Underfocus b: In-focus c: Overfocus

Fig. 5.4-4 Focusing with the aid of the Fresnel fringe

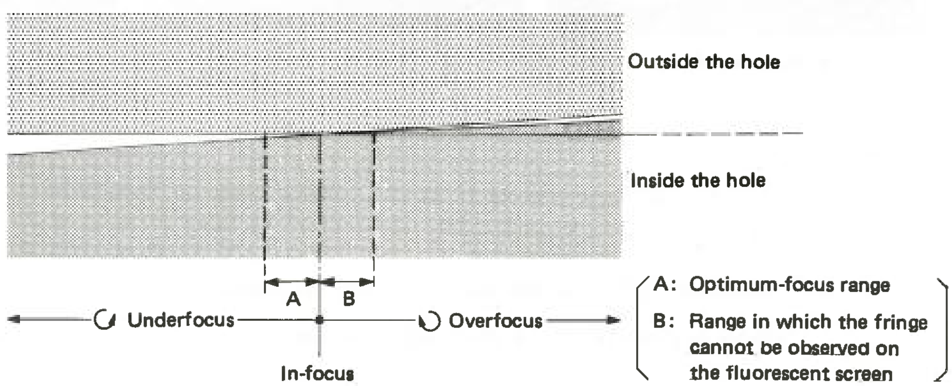


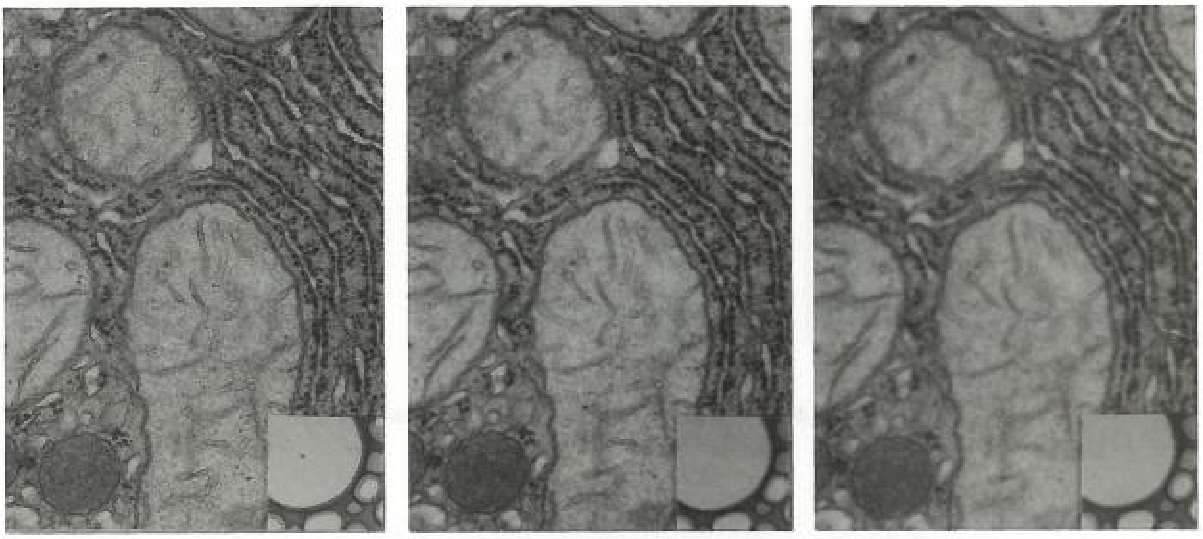
Fig. 5.4-5 Schematic diagram showing various focus conditions

3. Set the OBJ FOCUS: FINE knob (R1-3) to the in-focus position or slightly underfocus position (obtained by turning the knob slightly counterclockwise from the in-focus position).

   In the case of low-contrast specimens (such as very thin biological sections), the image should be slightly underfocused in order to obtain a sufficiently sharp image. In order to distinguish the focus suitable for

photography from in-focus, it is called 'optimum' focus (Fig. 5.4-5-A).

Fig. 5.4-6 shows a very thin biological section photographed under various focal conditions. In the figure, (a) is an optimum-focus (slightly underfocused) image, (b) is an in-focus image, and (c) is an overfocused image. If the OBJ FOCUS: FINE knob (R1-3) is turned counterclockwise beyond the optimum-focus range, the image becomes indistinct like a relief and the resolution deteriorates drastically. If the image is overfocused, it becomes impossible to interpret the image correctly. Never use an overfocused image for photography.



a: Optimum-focus **b: In-focus** **c: Overfocus**

Fig. 5.4-6 Practical example of focusing

Note: It is rather difficult to focus an image of very low contrast using the Fresnel fringe. Accordingly, in such case, if the magnification is relatively low, use the image wobbler, or set the OBJ FOCUS: FINE knob (R1-3) to the position where the contrast is lowest (almost the in-focus position) by turning it clockwise from the underfocus side. This method, however, requires some experience.

5.4.4 Image recording

Automatic exposure requiring films to be advanced one by one, described in Sect. 5.2, is omitted in this subsection. See Sect. 5.9 for photography of a tilted specimen.

5.4.4a Manual exposure

Use this method if the exposure time is to be freely set without using the exposure meter.

1. Release the SHUTTER AUTO button (R1-6) and FILM ADVANCE AUTO button (R1-7).
2. Select the desired magnification and field of view, and focus the image.
3. Set the exposure time.
   3a. Let the CRT display PAGE-1.
   3b. Set the EXP TIME value on PAGE-1 to the desired exposure time with the EXP TIME switch (R1-5).
4. Depress the PHOTO button (L1-12). When the built-in lamp lights up, depress the button again.

5.4.4b Continuous photography

In this method, an unexposed film is automatically advanced to the exposing position every time the image is photographed.

1. Depress the FILM ADVANCE AUTO button (R1-7).
2. Select the desired magnification and field of view, and focus the image.
3. Adjust the image brightness. In the case of manual exposure, set the exposure time.
4. After confirming that the PHOTO button (L1-12) lamp is lit, depress the PHOTO button (L1-12). The first film is now exposed. Repeat Steps 2 to 4 for the second and later films. For the last exposure, however, carry out Step 5.
5. For the last exposure, proceed as follows:
   5a. Release the FILM ADVANCE AUTO button (R1-7).
   5b. Select the desired magnification and field of view, focus the image, and adjust the image brightness or exposure time.
   5c. Depress the PHOTO button (L1-12).
   5d. When the built-in lamp of the PHOTO button (L1-12) lights up, depress the button again.

5.4.4c Multiple exposure

By using this method, a film can be exposed as many times as required.

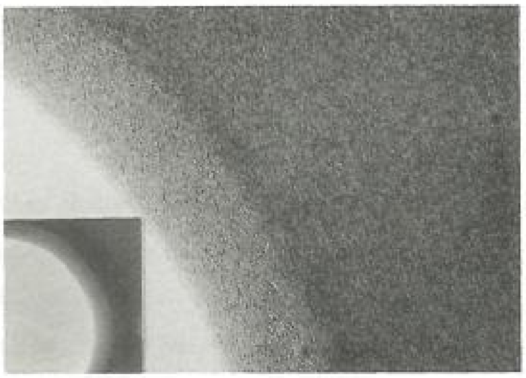
1. Select the desired magnification and field of view, and focus the image.
2. Adjust the image brightness. In the case of manual exposure, set the exposure time.

3. If the built-in lamp of the PHOTO button (L1-12) is not lit, depress the PHOTO button (L1-12), and wait for the built-in lamp to light up.
4. After confirming that the built-in lamp of the PHOTO button (L1-12) is lit, depress the button. The large fluorescent screen now becomes upright, the film is exposed (the EXP lamp (L1-13) lights up and remains lit while the shutter is open), and the large fluorescent screen then returns to the horizontal position. When the large fluorescent screen starts returning to the horizontal position, redepress the PHOTO button (L1-12) before the screen becomes completely horizontal.
5. By repeating Steps 1 to 4, expose the film as many times as required. After the last exposure, however, do not depress the PHOTO button (L1-12) when the large fluorescent screen starts returning to the horizontal position.

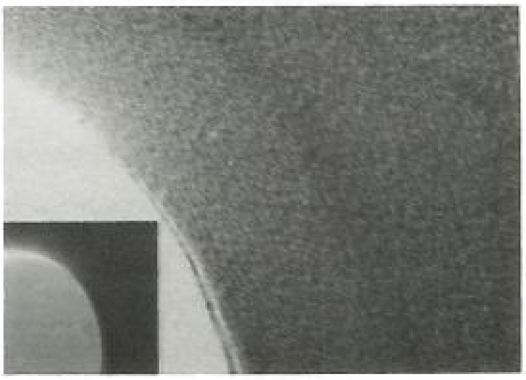
5.5 Conditions for high magnification/high resolution microscopy

A. The voltage center must be properly aligned.

Fig. 5.5-1a shows a hole image when the voltage center is properly aligned. In this figure, the background structure (phase contrast) is readily discernible, and the edge of the hole can be clearly observed all the way round. On the other hand, Fig. 5.5-1b shows a hole image when the voltage center is misaligned. In this figure, the image is indistinct, the background structure appears unidirectional, and the edge of the hole is blurred as if astigmatism exists.



a: Hole image when voltage center is aligned



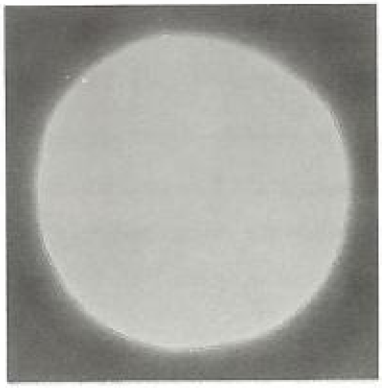
b: Hole image when voltage center is misaligned

Fig. 5.5-1 Effect of voltage center alignment

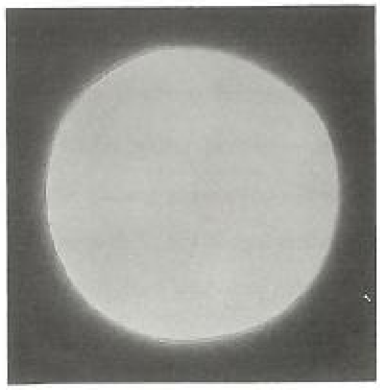
For high-magnification photography, realign the voltage center at the photographing magnification by using the WOBBLER: HT button switch (R1-4).

B. The objective lens aperture must be properly inserted.

Fig. 5.5-2a shows a hole image when the objective lens aperture is properly inserted into the electron beam path. In this figure, the background structure is readily discernible, and the edge of the hole can be clearly observed all the way round. On the other hand, Fig. 5.5-2b shows a hole image when the aperture is improperly inserted. In this figure, the image is indistinct, the background structure exhibits unidirectional blurring, and the edge of the hole appears as if astigmatism exists.



a: Hole image when aperture is properly inserted into beam path



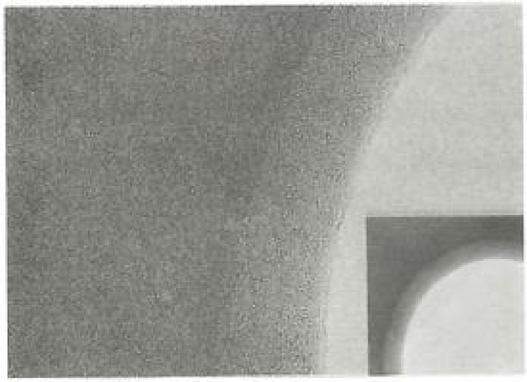
b: Hole image when aperture is improperly inserted into beam path

Fig. 5.5-2 Effect of objective lens aperture insertion

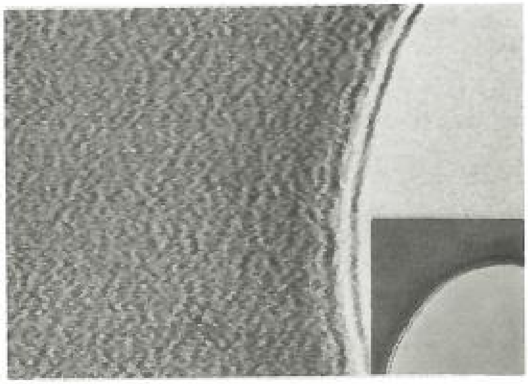
C. The objective lens astigmatism correction must be complete.

If astigmatism exists in the objective lens, the focusing becomes unidirectional, and it will be impossible to focus the image correctly in all directions. To illustrate the point, Fig. 5.5-3a shows a hole image when the lens is free from astigmatism, and Fig. 5.5-3b shows the same image when lens astigmatism is present. It will be seen that when the lens is free from astigmatism, the background structure is clear and the edge of the hole can be readily observed all the way round; and that when lens astigmatism is present, the image is blurred and the Fresnel fringe is asymmetrical around the edge of the hole.

Astigmatism correction should be carried out at a magnification higher than that used for actual photography. However, once astigmatism correction is complete, photography can be carried out at lower magnifications without the need to repeat astigmatism correction. If the amount and direction of astigmatism vary as



a: Hole image when astigmatism does not exist



b: Hole image when astigmatism exists

Fig. 5.5-3 Effect of objective lens astigmatism

time goes by, a dirty objective lens aperture or dirty specimen holder is indicated. In this case, clean the contaminated part/parts as per Chap. 6.

Utilizing the background structure in conjunction with the Fresnel fringe (at slightly overfocus) is extremely effective when correcting objective lens astigmatism at magnifications of 100,000X or more. That is to say, after first of all removing the astigmatism as much as possible using the Fresnel fringe, focus the image and then remove any remaining astigmatism so as to make the background structure as clear as possible.

D. The specimen must be tightly secured.

If the specimen is not tightly secured, it will result as time passes in a gradual shift of the specimen (image). This phenomenon is referred to as "image drift". Fig. 5.5-4a shows a hole image under drift-free conditions, and Fig. 5.5-4b shows the same image when image drift exists. In the former, the background structure is distinct, and the edge of the hole can be clearly discerned all the way round. In the latter case, the background structure appears to be unidirectional, and the edge of the hole exhibits one-way blurring.

a: Hole image when there is no drift

b: Hole image when there is drift

Fig. 5.5-4 Effect of image drift

The chief causes of image drift and the countermeasures to be taken are as follows:

- Damaged, wrinkled, improperly secured and/or insufficiently strong supporting film
  Exercise great care when preparing the supporting film. Use adequate adhesive when securing the film to the grid, and reinforce the film using the carbon coating method.
- Bent specimen grid
  Discard and replace with new (unbent) grid.
- Electrically charged specimen and/or supporting film
  Enhance conductivity by coating the specimen and/or supporting film with carbon.

E. The image must be properly focused.

Utilizing the background structure in conjunction with the Fresnel fringe (overfocus or underfocus) is very effective for increasing the focusing accuracy when focusing images at magnifications of 100,000× or more. That is to say, focus the image as precisely as possible with the fringe at underfocus, and then finely focus the image (in-focus) so as to minimize background structure contrast. A further point to keep in mind when focusing images at high magnifications is that, since the possibility of mistaking the apparent fine structure for the actual structure is large, it is necessary to photograph several images while changing the focus very slightly (through-focus method) and to select the optimum-focus image from among the ones photographed (see Sect. 5.6).

Fig. 5.5-5 shows micrographs of perforated film obtained by the through-focus method. These micrographs clearly indicate that the background structure varies according to defocusing (Fresnel fringe variation).

a: Underfocus b: In-focus c: Overfocus

Fig. 5.5-5 Fresnel fringe and background structure variation

F. Others

If the specimen is contaminated, it is difficult to focus the image correctly, and photographs obtained will be obscure even though the image is properly focused. In order to prevent contamination by the electron beam, avoid irradiating the specimen for a long time, and use the anticontamination device (see Sect. 5.8). Do not use a magnification higher than that necessary for resolving the feature of interest adequately, and photograph the image with an exposure time as short as possible (two to four seconds will be adequate). If the apertures are contaminated, they may cause astigmatism. Clean them periodically as per Chap. 6.

5.6 Special observations

5.6.1 Low magnification images

1. Carry out column alignment.
2. Remove the objective and field limiting apertures from the electron beam path.
3. Depress the LOW MAG button (R1-8), and spread the electron beam with the BRIGHTNESS knob (L1-14).
4. Select the desired magnification with the SELECTOR switch (R1-9). The selected magnification is displayed on PAGE-1 on the CRT.
5. Align the voltage center.
   5a. Depress the WOBBLER: HT button (R1-4) and BRIGHT TILT button (L1-15).
   5b. Align the voltage center with the DEF: X and Y knobs (L1-17, R1-2).
   5c. Release the WOBBLER: HT button (R1-4) and BRIGHT TILT button (L1-15).

   Note: When the BRIGHT TILT button switch (L1-15) is off, manipulation of the DEF: X and Y knobs (L1-17, R1-2) does not affect the voltage center.
6. Check astigmatism.
   6a. Depress the OBJ STIG 1 button (L1-15).
   6b. Depress the IMAGE X button (R1-4) and focus the image with the OBJ FOCUS knobs (focusing with the image wobbler).
   6c. Release the IMAGE X button (R1-4), and depress the IMAGE Y button (R1-4). If the image is doubled, carry out Step 7 in order to correct the astigmatism. If the image is not doubled, proceed to Step 8.
7. Correct the astigmatism.
   7a. Manipulate the DEF: Y knob (R1-2) so that the double image which appears when the IMAGE Y button (R1-4) is depressed becomes a single stationary image.
   7b. Manipulate the DEF: X knob (L1-17) so that the double image which appears when the IMAGE X button (R1-4) is depressed becomes a single stationary image.
   7c. Repeat Steps 7a and 7b until the image appears as a single stationary image in both Steps 7a and 7b.
8. Release the OBJ STIG 1 button (L1-15) and IMAGE X and Y buttons (R1-4).

   Note: When the OBJ STIG 1 button (L1-15) is released, manipulation of the DEF: X and Y knobs (L1-17, R1-2) does not affect astigmatism.
9. To heighten image contrast, insert a field limiting aperture into the electron beam path.
   9a. Reduce the magnification with the SELECTOR switch (R1-9).
   9b. Set the field limiting aperture assembly lever to the left side. If the illumination disappears from the fluorescent screen, manipulate knobs 2 and 3 so as to align the aperture (see Fig. 5.6-1).

9c. Select the desired aperture size with knob 1.

9d. Correctly align the aperture with knobs 2 and 3.

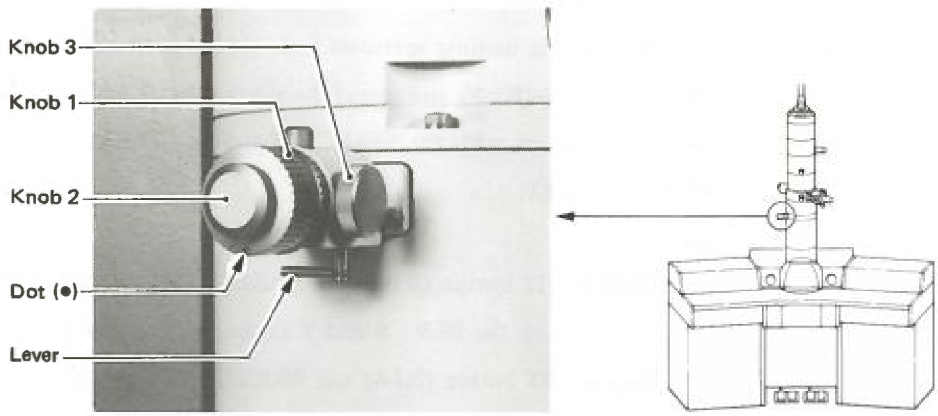
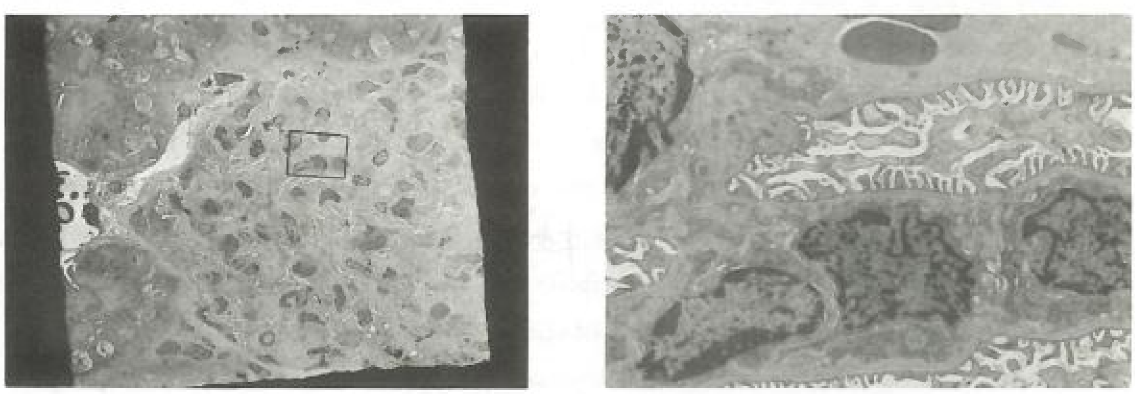


Fig. 5.6-1 Field limiting aperture assembly

10. Focus the image with the image wobbler, and photograph the image.

Note: Photograph the image with the small fluorescent screen inserted into the beam path since the exposure meter does not operate properly when the large fluorescent screen is not illuminated entirely.



a: Low magnification image **b: Enlarged image of the enclosed area in (a)**

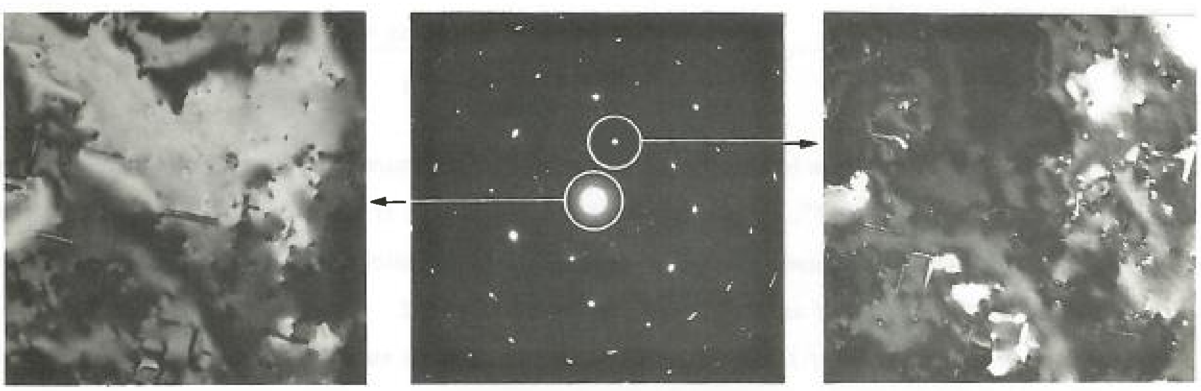
Fig. 5.6-2 Low magnification image

5.6.2 Dark field images

When the incident electron beam passes through the specimen, it splits chiefly into unscattered electron beam and scattered (diffracted) electron beam; the former forms a bright field image, and the latter a dark field image. Though the dark field image does not provide sufficient image brightness, it has an advantage that image contrast is much greater than that of a bright field image.

1. Carry out column alignment.
2. Depress the MAG 1 button (R1-8), and select the desired magnification with the SELECTOR switch (R1-9).
3. Select the desired field of view, and roughly focus the image.
4. Remove the objective lens aperture from the electron beam path.
5. Depress the DIFF button (R1-8), and spread the illumination with the BRIGHTNESS knob (L1-14). A diffraction pattern now appears on the fluorescent screen.
6. Set the camera length to a value between 40 and 120 cm with the SELECTOR switch (R1-9). (The selected camera length is displayed on PAGE-1 on the CRT.)
7. Manipulate the DIFF FOCUS knob (R1-10) so as to obtain the sharpest possible diffraction pattern.
8. Manipulate the PROJ ALIGN knobs (R2-3) so as to precisely center the direct spot on the fluorescent screen.

   Note: The bright spot at the center of the diffraction pattern is referred to as the direct spot.
9. Depress the DARK TILT button (L1-15), and then set the DEF: X and Y knobs (L1-17, R1-2) to the midway position.
10. Manipulate the DEF: X and Y knobs (L1-17, R1-2) so as to precisely center the desired spot on the fluorescent screen. If the illumination shifts when moving the diffraction pattern, recenter it with the SHIFT: X



a: Bright field image **b: Diffraction pattern (aperture position)** **C: Dark field image**

Fig. 5.6-3 Comparison of bright and dark field images

and Y knobs (L1-16, R1-1).

11. Insert the objective lens aperture into the electron beam path, and precisely align the aperture center with the screen center. The aperture image can be focused with the DIFF FOCUS knob (R1-10).
12. Depress the MAG 1 button (R1-8). A dark field image now appears on the fluorescent screen. A bright field image can be obtained by simply depressing the BRIGHT TILT button (L1-15).

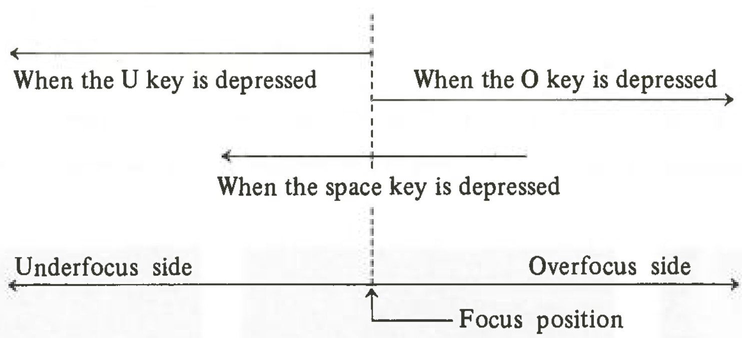
5.6.3 Through-focus method

This is a method to take several photographs by changing the focus very slightly. The through-focus photography is automatically carried out in accordance with the number of films to be exposed and the focus step per film as input through the keyboard.

1. Switch off the OBJ 16× button (R1-3).
2. In the case of automatic exposure, switch on the SHUTTER AUTO button (R1-6). In the case of manual exposure, switch off the SHUTTER AUTO button (R1-6) and set the exposure time.
3. Input the number of films to be exposed and the amount of focus change per film.

3a. Depress the THRU FOCUS key (KB-1). "TF N =" and "ΔF = Δ*" are displayed in the bottom margin of PAGE-1.

3b. Depress the U, O or space key (KB-2) between the TF and N. When the U, O or space key is depressed, focus changes as follows:



3c. Write the number of films to be exposed (up to 50) and the amount of focus change (1 to 9) in the space after "N =" and "Δ*", respectively (see Subsect. 5.2.11f). If the number of films to be exposed exceeds the number of unused films, set additional films as required in the dispensing magazine.

Notes: 1. The number of unused films is displayed on PAGE-1.

2. The amount of focus change (1 to 9) indicates the number of OBJ FOCUS: FINE knob (R1-3) knotches.

3d. Depress the RETURN key (KB-2). If "ERROR" appears in the bottom margin, restart from Step 3a.

4. Depress the THRU FOCUS key (KB-1) again.
5. Focus the image.

6. After confirming that there is sufficient room in the receiving magazine, depress the PHOTO button (L1-12).

5.6.4 Minimum exposure operation (MDS)

By using the MDS, electron beam irradiation on the specimen can be considerably reduced.

1. Obtain PAGE-1 with the PAGE key (KB-1).
2. Adjust the image brightness and exposure time (manual exposure).
3. Depress | M | D | S | RETURN | (KB-2). When "MDS-0" appears in the bottom margin of PAGE-1, depress the RETURN key (KB-2) again.
   "MDS-1" is now displayed in the bottom margin and image brightness and exposure time are stored.
4. Depress the IMAGE SHIFT button (L1-15).
5. Reduce image brightness as much as possible and center the desired field of view for recording with the specimen shifting knobs.
6. Depress the RETURN key (KB-2).
   "MDS-2" is now displayed in the bottom margin of PAGE-1 and the field view is stored.
7. Set the magnification to a value for recording.
   Note: The magnification value is not stored.
8. Move the field of view for recording off the fluorescent screen with the DEF knobs (L1-17, R1-2).
9. Brighten the image and focus it.
10. Depress the RETURN key (KB-2).
    "MDS-3" is now displayed in the bottom margin of PAGE-1.
11. Move the illumination with the SHIFT knobs (L1-16, R1-1) in the opposite direction to that in Step 8.
12. Depress the PHOTO button (L1-12). Recording starts after about 10 seconds.
13. To continue photography, display "MDS-1" in the bottom margin of PAGE-1 with the RETURN key (KB-2) and repeat steps from Step 5. If a need arises to change image brightness and exposure time, carry out Step 14 and restart from Step 1.
14. Depress | M | D | S | RETURN | to return to normal operation.

5.7 Electron diffraction

This section describes three diffraction methods: selected area electron diffraction, microbeam electron diffraction, and high dispersion electron diffraction. Refer to the EM-AD instruction manual for high resolution electron diffraction.

5.7.1 Selected area electron diffraction

In this method, a diffraction pattern is formed by the electron beam passing through a small area limited by the intermediate lens aperture.

1. Carry out column alignment, and insert the specimen into the electron beam path.
2. Depress the DIFF button (R1-8), and set the camera length to 250 cm with the SELECTOR switch (R1-9).

   Note: The camera length is displayed on the DIFF line on PAGE-1.
3. Manipulate the DIFF FOCUS knob (R1-10) so as to obtain the sharpest possible direct spot. If the spot is not at the center of the fluorescent screen, center the spot with the PROJ ALIGN knobs (R2-3).
4. Insert the field limiting aperture into the electron beam path.

   4a. Set the field limiting aperture assembly lever to the left side. If this causes the image to disappear, reduce the magnification, and manipulate knobs 2 and 3 so as to align the aperture (see Fig. 5.6-1).

   4b. Select the desired aperture size with knob 1.

   4c. Focus the field limiting aperture image with the DIFF FOCUS knob (F1-10).

   4d. Center the aperture image with knobs 2 and 3.
5. Depress the SAM/ROCK button (R1-8) and select the desired field of view and magnification.
6. If necessary, record the image (selected area image, Fig. 5.7-1).
7. Remove the objective lens aperture from the electron beam path.
8. Depress the DIFF button (R1-8), and select the camera length between 10 cm and 250 cm with the SELECTOR switch (R1-9).

   Note: The camera lengths that can be switched are 10 to 250 cm, 400 cm to 80 m, and 33.8 cm. The 10 cm to 250 cm camera lengths are for selected area electron diffraction, the 400 cm to 80 m camera lengths for high dispersion electron diffraction, and the 33.7 cm camera length is for high resolution electron diffraction.
9. Focus the diffraction pattern with the DIFF FOCUS knob (R1-10).
10. Block the direct beam with the beam stopper knob (option).
11. Darken the diffraction pattern with the BRIGHTNESS knob (L1-14) to the extent that the pattern is just

discernible on the fluorescent screen, and record the pattern by manual exposure. An exposure time of about 1 minute is recommended.

Note: If the direct spot is also to be recorded, remove the beam stopper 1 to 2 seconds before completing the exposure.

a: Selected area image

b: Selected area diffraction pattern

Fig. 5.7-1 Selected area electron diffraction

5.7.2 Microbeam electron diffraction

In this method, a diffraction pattern is formed by the finely converged electron beam illuminating only a very small area on the specimen.

1. Carry out column alignment, and insert the specimen into the electron beam path.
2. Depress the DIFF button (R1-8), and set the camera length to 250 cm with the SELECTOR switch (R1-9).
   Note: The camera length is displayed on the DIFF line on PAGE-1.
3. Manipulate the DIFF FOCUS knob (R1-10) so as to obtain the sharpest possible direct spot. If the spot is not at the screen center, center the spot with the PROJ ALIGN knobs (R2-3).
4. Depress the MAG 1 button (R1-8), and select a magnification between 4,000X and 500,000X.
5. Precisely center the feature of interest, and focus the image.
6. Record the image (first one of double exposure) as described in Sect. 5.4.4c (multiple exposure).
7. Remove the objective lens aperture from the electron beam path, and select the large condenser lens aperture.
8. Minimize the spot size with the SPOT SIZE switch (L1-8), and converge the electron beam with the BRIGHTNESS knob (L1-14).
9. Center the converged electron beam with the SHIFT: X and Y knobs (L1-16, R1-1). This aligns the converged beam with the feature of interest.

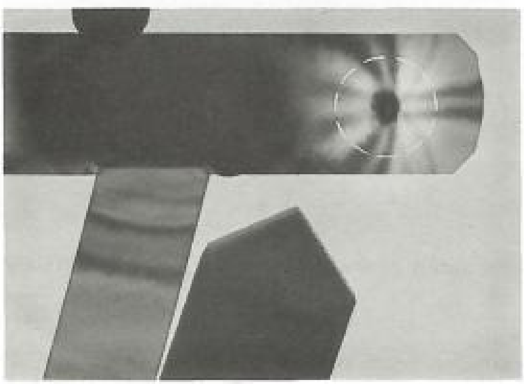
Caution: After this step, do not turn the SHIFT: X, Y and BRIGHTNESS knobs, and do not shift the specimen.

10. Record the beam spot (second one of double exposure) in accordance with Sect. 5.4.4c (multiple exposure).

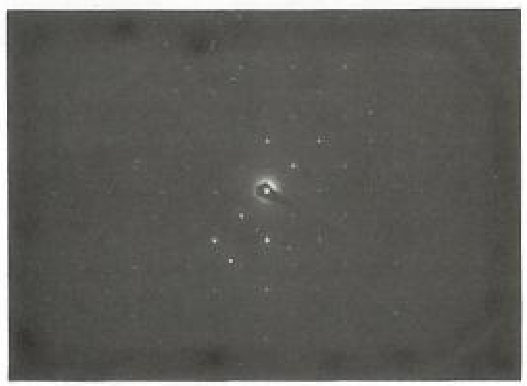
    Note: By the first exposure (Step 6), the whole field of view is photographed and by the second, the beam spot in the feature of interest is photographed on the same film (Fig. 5.7-2a).

11. Depress the DIFF button (R1-8), and set the camera length to 10 cm with the SELECTOR switch (R1-9).
12. Focus the diffraction pattern with the DIFF FOCUS knob (R1-10).
13. Block the direct beam with the beam stopper knob (Fig. 3.3-1).
14. Record the diffraction pattern by manual exposure.

    Note: If the direct spot is also to be recorded, remove the beam stopper 1 to 2 seconds before completing the exposure.



a: Beam spot and image



b: Microbeam diffraction pattern

Fig. 5.7-2 Microbeam electron diffraction

5.7.3 High dispersion electorn diffraction

The maximum lattice spacing that can be analyzed by the selected area diffraction method is on the order of tens of Ångstroms. This can be extended, however, to several thousand Ångstroms by means of the high dispersion diffraction method. However, since the specimen in this method is easily charged, coat the specimen on both sides with carbon if specimen conductivity is very low.

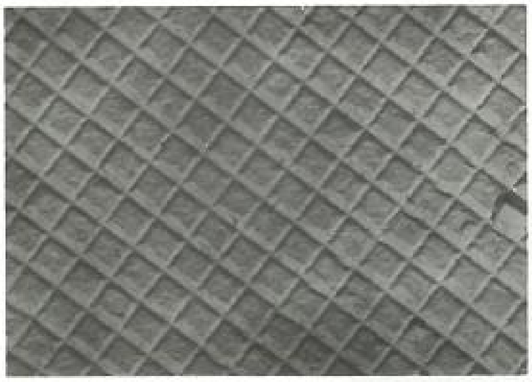
1. Carry out column alignment, and insert the specimen into the electron beam path.
2. Depress the MAG 1 button (R1-8), and select the desired magnification.
3. Select the desired field of view, and record the image.
4. Depress the LOW MAG button (R1-8), obtain a magnification of about 500×, and focus the image.
5. Spread the electron beam over the field of view with the BRIGHTNESS knob (L1-14), and bring the

desired feature to the fluorescent screen center.

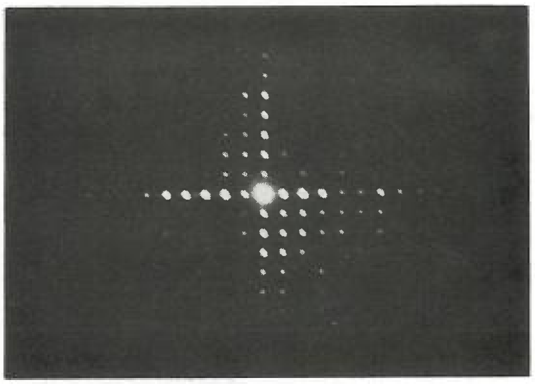
6. Select the small objective lens aperture, and align the center of the aperture image with the fluorescent screen center.
7. If necessary, record the image.
8. Depress the DIFF button (R1-8), and obtain a camera length of 400 cm or longer with the SELECTOR switch (R1-9).

Note: The camera lengths that can be switched are 34.5 cm, 10 to 250 cm, and 400 cm and longer. The 34.5 cm camera length is for high resolution electron diffraction, the 10 cm to 250 cm camera lengths are for selected area electron diffraction, and the 400 cm and longer camera lengths for high dispersion electron diffraction.

9. Focus the direct spot with the DIFF FOCUS knob (R1-10). If the direct spot is not on the fluorescent screen, turn the BRIGHTNESS knob (L1-14) counterclockwise to find the direct spot, center it with the SHIFT X and Y knobs (L1-16, R1-1), repress the DIFF button (R1-8) and focus it with the DIFF FOCUS knob (R1-10).
10. Record the diffraction pattern by manual exposure.



a: Micrograph of optical replica



b: Corresponding high dispersion diffraction pattern

Fig. 5.7-3 High dispersion electron diffraction

5.8 How to use the anticontamination device

By proper use of the anticontamination device, specimen contamination rate is reduced. It is therefore useful when observing valuable specimens or when microscopy is being carried out at high magnification and high resolution. Moreoever, even in routine microscopy, use of the anticontamination device allows ample time to be taken for selecting the field of view and focusing the image.

5.8.1 Filling the refrigerant tank

1. Confirm that the PENNING GAUGE (L2-10) reading is 0.1 Pa (10^{-3} Torr) or less.

   Caution: If refrigerant is poured into the refrigerant tank when the column pressure is over 0.1 Pa (10^{-3} Torr), residual water vapor in the column will condense into droplets and ice which will adhere to the cooling trap and cause corrosion and electron beam charging. This, in turn, adversely affects objective lens astigmatism, and the image and illumination become unstable.
2. Remove the cap from the refrigerant tank inlet port, and insert the refrigerant funnel (Sect. 3.2) into the port.
3. Fill the tank with liquid nitrogen (Fig. 5.8-1).
4. After about 15 minutes, again fill the tank with liquid nitrogen.
5. Remove the funnel, and replace the inlet port cap.
6. Replenish the tank with liquid nitrogen every hour in the case of continuous operation.

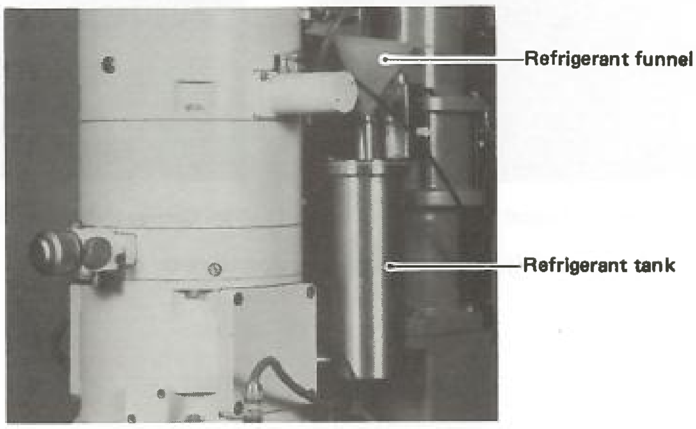


Fig. 5.8-1 Pouring in liquid nitrogen refrigerant

5.8.2 Raising the refrigerant tank temperature to room temperature

If air is admitted into the column with the anticomtamination device cooling trap in the cooled state, atmospheric moisture will condense into water droplets which will adhere to the trap, causing troubles such as electrical charging. In order to prevent this, the refrigerant tank must be drained and the trap heated to room temperature before admitting air into the column.

1. Cover the viewing windows with the lids as provided.
2. Remove the cap from the refrigerant tank inlet port, and insert the refrigerant drainer (Sect. 3.2) as shown in Fig. 5.8-2.

   Caution: *Since the refrigerant remaining in the tank passes through the drain tube at a fairly brisk rate and may splash against you or the viewing window, have a suitable plastic container ready and insert the free end of the drain tube into the container before inserting the drainer into the tank.*

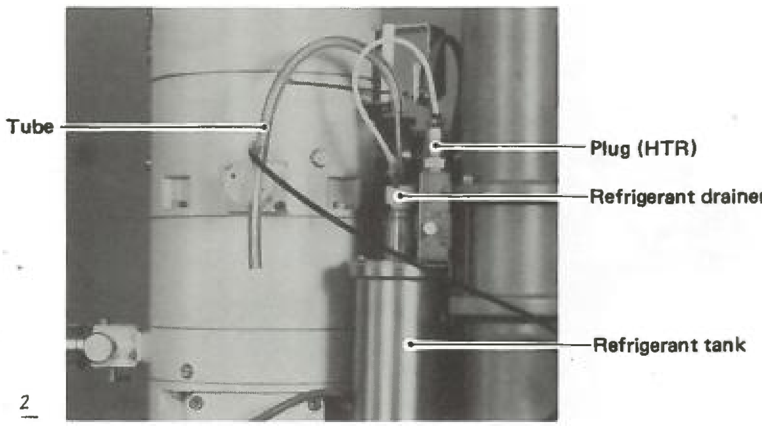


Fig. 5.8-2 Draining off the refrigerant

3. Insert the refrigerant drainer plug into the anticontamination device socket (HTR).
4. Depress the ACD HEAT button (L2-6). The built-in lamp of the button now lights up. Wait for the lamp to go out (about 15 minutes).
5. When the lamp goes out, remove the refrigerant drainer, and again wait for about 15 minutes.

   Notes: *1. If the refrigerant drainer plug is disconnected while the ACD HEAT button lamp is lit, the lamp will remain lit. In this case, re-insert the plug, and wait for the lamp to go out.*

   2. If it is desired to terminate trap heating before the trap reaches room temperature, depress the ACD HEAT button (L2-6), and keep it depressed (for several seconds) until the button lamp goes out.

5.9 How to use the goniometer

By using the goniometer, the specimen can be freely tilted.

5.9.1 Specimen tilting

1. Select the X-tilting speed with the X-TILT knob (L1-18).
2. Confirm that the lamp (Fig. 5.9-1) is lit.

   Note: If the lamp is not lit, the following step to tilt the specimen cannot be carried out.
3. Tilt the specimen with one of the X pedal switches. If the image shifts more than a little when the specimen is tilted, return the X-tilt angle to 0°, and align the specimen tilt axis as described in Sect. 5.9.2.
4. Read the X-tilt angle on the graduated scale engraved on the X-tilt knob (Fig. 5.9-1).

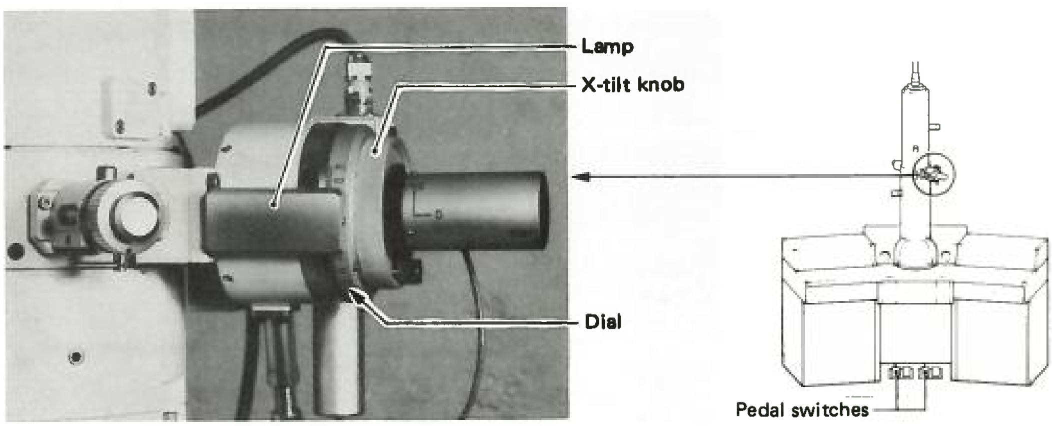


Fig. 5.9-1 X-tilt knob

5.9.2 Tilt axis alignment

The image will not shift when the specimen is tilted so long as the specimen tilt axis accords with the specimen surface and is intersecting the optical axis of the microscope column. If the image shifts when the specimen is tilted, align the tilt axis as follows:

1. Confirm that the X-tilt angle is 0°.
2. Obtain a low magnification image (500X to 600X).
   2a. Depress the LOW MAG button (R1-8).
   2b. Obtain a magnification of from 500X to 600X with the SELECTOR switch (R1-9).
   The magnification is displayed on PAGE-1 on the CRT.
3. Set the left specimen shifting knob to its midway position.
   3a. Make the CRT display PAGE-2.
   3b. Zero the P-X value on PAGE-2 with the left specimen shifting knob.
4. Disengage the motor from the goniometer by pushing the motor (Fig. 5.9-2) towards the column rear. The lamp now goes out.

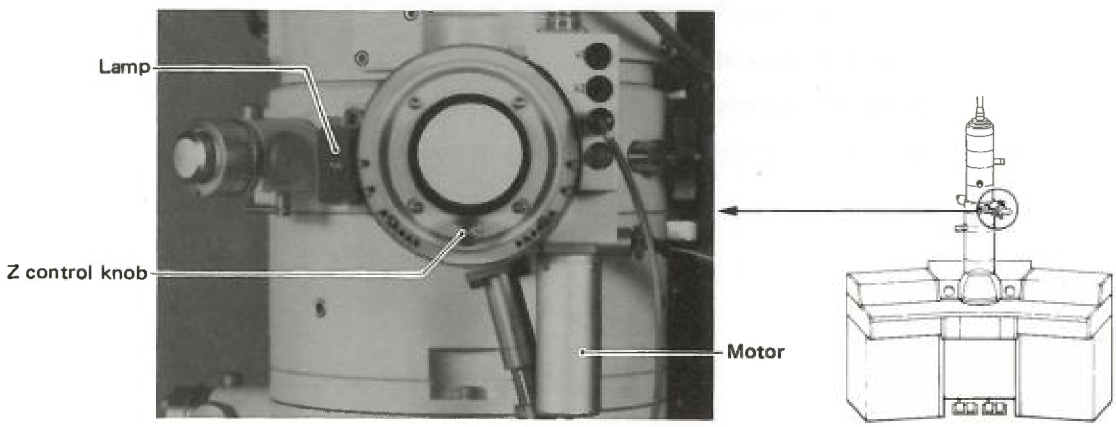


Fig. 5.9-2 Lamp, motor, and Z control knob

5. Turn the X-tilt knob fully counterclockwise.
6. Bring some feature in the image to the screen center with the specimen shifting knobs.
7. After turning the X-tilt knob fully clockwise, note the position of the feature.
8. Position the feature midway between the screen center and the position noted in Step 7 with the Z control knob (Fig. 5.9-2).
9. Repeat Steps 5 to 8 until the position of the feature, with the X-tilt knob turned fully clockwise, coincides with the position of the feature when the knob is turned fully counterclockwise. The tilt axis now accords

with the specimen surface.

10. Adjust the axis alignment screws (Fig. 5.9-3) so that the feature remains stationary when the X-tilt knob is turned. The X-tilt axis now intersects the optical axis of the microscope column.

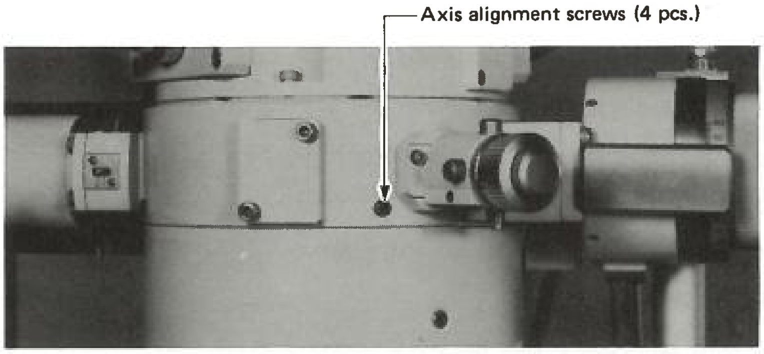


Fig. 5.9-3 Axis alignment screws

11. Carry out Steps 5 to 10 at magnifications of 5,000× and 10,000×.
12. Engage the motor gear and the goniometer gear by pulling the motor (Fig. 5.9-2) to the fullest extent. The goniometer lamp lights up.

    Note: If the motor and goniometer gears are improperly engaged, the lamp fails to light up. In that case, slightly turn the X-tilt knob until the lamp lights up.

5.10 Use of the objective lens pole piece SAP

The SAP allows the specimen to be tilted at larger angles, while the SHP is used for high resolution microscopy. As far as operation is concerned, the SAP differs from the SHP only in the following points. (See Chap. 6 for pole piece exchange.)

1. The magnification and camera length values described in this chapter must be multiplied 1/2 and 2 times, respectively. In the case of low magnification images (LOW MAG), high dispersion electron diffraction (HD DIFF), or high resolution electron diffraction (HR DIFF), however, said multiplications are not necessary since the objective lens in these cases is not excited.
2. The specimen can be tilted up to ±60° with the goniometer. Therefore, set the X-tilt angle limiting screws to 60° (see Sect. 5.2.6).
3. Every type of specimen holder can be used.
4. The objective lens pole piece name on PAGE-1 should be changed to "SAP" using the MAG (KB-1) key (Fig. 5.2-24).

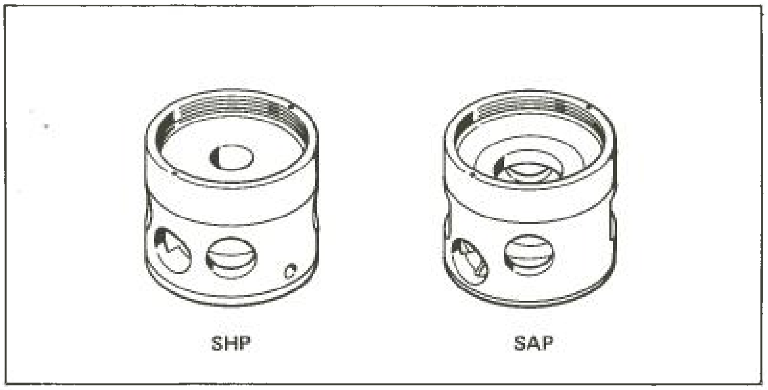


Fig. 5.10-1 Objective lens pole pieces

6. MAINTENANCE

6. MAINTENANCE

This chapter deals mainly with routine and preventive maintenance for ensuring peak instrument performance at all times.

The symbols L1, L2, R1, R2, and KB appearing in parentheses after the names of panel controls designate the respective control panels (see Fig. 3.5-1).

6.1 Electron gun filament replacement

6.1.1 Ascertaining the electron gun filament burnout

1. Generate an accelerating voltage.
2. Obtain the maximum **BIAS MODE (L1-7)** value with the **BIAS MODE: COARSE** and **FINE** switches (L1-7).
3. Confirm that valve V3 is open (the valve conditions are displayed on PAGE-3).

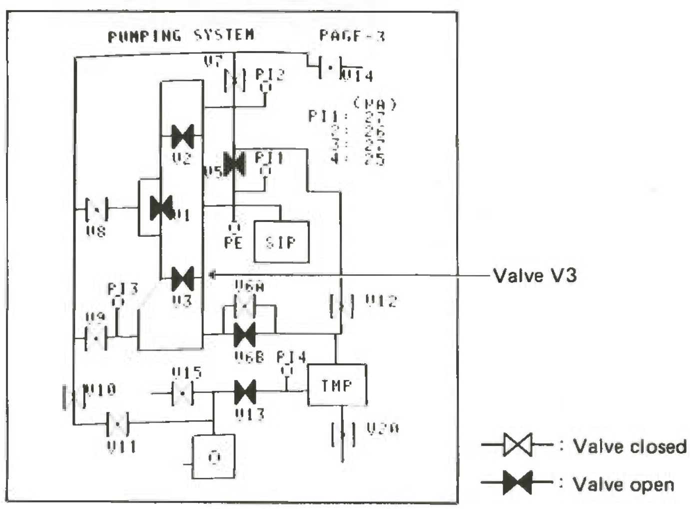


Fig. 6.1-1 PAGE-3

4. Turn the **FILAMENT** knob **(L1-2)** fully clockwise, and ascertain that this does not cause the **BEAM CURRENT** (L1-1) reading to increase.

   Note: If the meter reading increases, the filament is not burnt out.

5. Return the BIAS MODE (L1-7) reading to the original value (between 70 and 80), and set the FILAMENT knob (L1-2) stopper at the original position.

6.1.2 Admitting air into the anode chamber

6. Position the FILAMENT knob (L1-2) to OFF, and release the HT button (L1-6).
7. If the lift and anode chamber are connected by flat bars, remove the bars (Fig. 6.1-2).

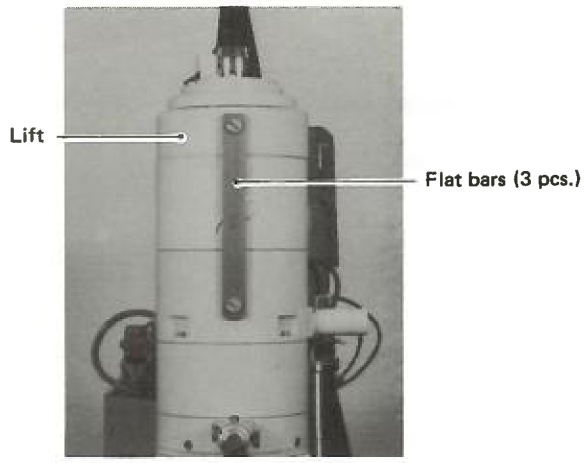


Fig. 6.1-2 Flat bars

8. Position the LIFT switch (L2-1) at ON.
9. Depress the GUN AIR button (L2-4). Air is admitted into the anode chamber and the electron gun is hoisted by the lift.
10. Cover the anode chamber with aluminum foil or the like to keep out dust.

6.1.3 Filament replacement

11. Confirm that the grounding device is in contact with the Wehnelt assembly (tip of the electron gun) and wait for the assembly to cool down.

    Caution: The Wehnelt assembly remains hot for some time after the filament has burnt out. Accordingly, allow a few minutes for the assembly to cool down before handling.

12. Remove the cylinder by turning it counterclockwise (Fig. 6.1-3).

    Caution: Be sure to wear clean, cotton or nylon gloves when handling the cylinder, Wehnelt assembly, etc. Dirt, perspiration, etc. from bare hands are a possible cause of high voltage discharge.

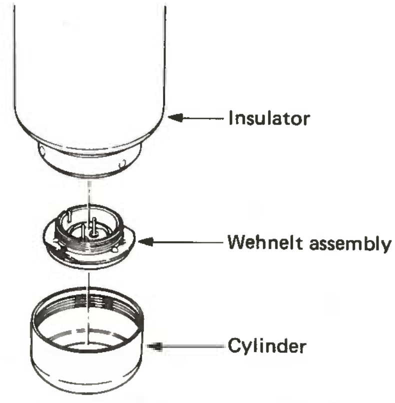


Fig. 6.1-3 Cylinder and Wehnelt assembly

13. Remove the Wehnelt assembly by pulling it downwards.
14. Disassemble the Wehnelt assembly as follows (Fig. 6.1-4):
    14a. Loosen the three filament securing screws with a hex key (Fig. 3.2-4), and remove the burnt-out filament (cathode) from the filament holder.
    14b. Remove the Wehnelt cap (grid) and spring from the filament holder by turning the cap counterclockwise.

    Note: If the cap is difficult to turn by hand, use the Wehnelt adjusting tool (Fig. 3.2-3).

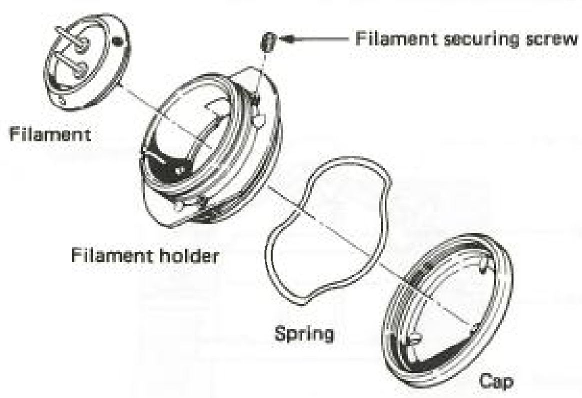


Fig. 6.1-4 Exploded view of Wehnelt assembly

15. Clean the Wehnelt cap (see Sect. 6.7).

16. Attach the spring to the filament holder and screw the cap onto the holder (1 to 2 turns).
    Apply the hand blower (Fig. 3.2-1) to the assembled unit to remove any traces of lint that may still be adhering.
17. Insert a new filament into the holder so that the filament base groove aligns with the holder pin, then secure the filament to the holder with the three filament securing screws.
    Caution: Be very careful not to touch the filament tip.

6.1.4 Adjusting the Wehnelt cap

18. As shown in Fig. 6.1-5, place the assembled Wehnelt on the pedestal of the Wehnelt adjusting tool (Fig. 3.2-3), then fit the Wehnelt adjusting tool cap over the Wehnelt assembly so that the cap pin aligns with one of the holes in the Wehnelt cap.
19. Adjust the position (height) of the Wehnelt cap as follows (Fig. 6.1-5):

FOR ASID.

19a. Screw in the Wehnelt cap by turning the Wehnelt adjusting tool cap clockwise until the tip of the Wehnelt cap is flush with the tip of the filament. 1.5

1turn + 1unit = ~~1½~~ turn $\boxed{1½}$

19b. Give the Wehnelt adjusting tool cap ~~2~~ turns in the counterclockwise direction to make the tip of the Wehnelt cap 1 mm higher than the tip of the filament.

Note: The Wehnelt adjusting tool cap is equipped with a calibrated scale which indicates the amount of cap displacement. Thus, one complete turn of the cap displaces the Wehnelt cap 0.5 mm up or down depending on the turning direction.

ASID= 1¼

TEM= 1½

19c. Remove the Wehnelt assembly from the tool.

1½ is currently correct 31-7-91

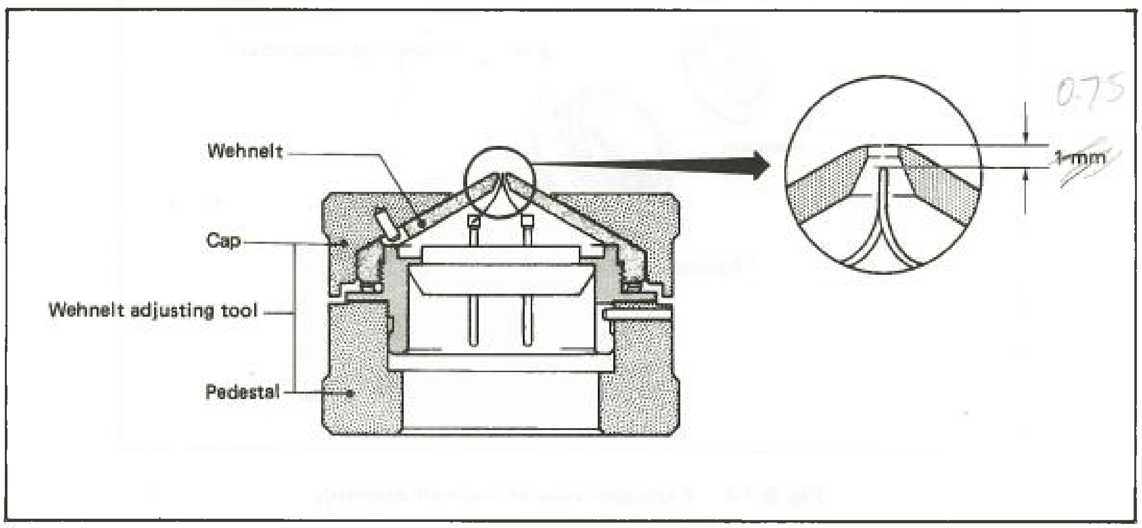


Fig. 6.1-5 Wehnelt cap adjustment

6.1.5 Re-evacuating the anode chamber

20. Mount the Wehnelt assembly in the electron gun socket by aligning the assembly groove with the socket pin, pushing the assembly into the socket as far as it will go, and securing the Wehnelt assembly with the cylinder.
21. Apply the hand blower to the electron gun O-ring and Wehnelt assembly to remove all traces of lint, dust, etc. Then, remove the aluminum foil covering the anode chamber and check the interior. Give the interior a good blow out with the hand blower. Lint, etc. remaining in the anode chamber may cause high voltage discharge. Check the O-ring too; a dirty O-ring can cause vacuum deterioration. Flip off with finger lint, etc. from the O-ring (be sure to wear gloves when doing this).
22. Release the GUN AIR button (L2-4). The electron gun now returns to its original position and the anode chamber is automatically evacuated.

Notes: 1. *When initially generating a high voltage after exchanging the filament, keep the anode chamber pressure below 5×10^{-6} Torr (5×10^{-4} Pa).*

2. *Since the filament saturation position may change after exchanging the filament, the FILAMENT knob (L1-2) stopper position should be adjusted in order to prevent the filament from overheating which shortens filament life.*

3. When initially generating high voltage, start at 40kV and increment in steps of 1kV, ~~not~~ allowing the beam current to stabilize at each step. (Use 1kV step if very unstable)

4. Go up to 95kV (110) and then return to 80kV.

N.B. Before turning on kV, ensure that:

- valves are open
- Penning gauge in green

6.2 Small fluorescent screen replacement

Long use of the fluorescent screen deteriorates the phosphor coated on the screen, with the result that the brightness and sharpness of the image are adversely affected. In such case, replace the effete small fluorescent screen with the spare one as provided, and contact your nearest JEOL Service Center to have the old screen re-conditioned. To replace the screen, proceed as follows:

1. Admit air into the viewing chamber.
   1a. Set the FILAMENT knob (L1-2) to OFF.
   1b. Turn the camera chamber door handle clockwise as far as it will go.
2. Fix the two suction disks (Fig. 3.2-1) on the viewing chamber window glass, and carefully remove the glass with both hands (Fig. 6.2-1).
   Place the removed glass in a clean spot with its inner surface facing upwards.
   Cautions: 1. Be careful not to touch or rub against the inner surface of the glass as it has been specially treated with conductive material.
   2. Be careful not to drop the window glass or bump its corners as it is lead glass which is brittle and easily broken.

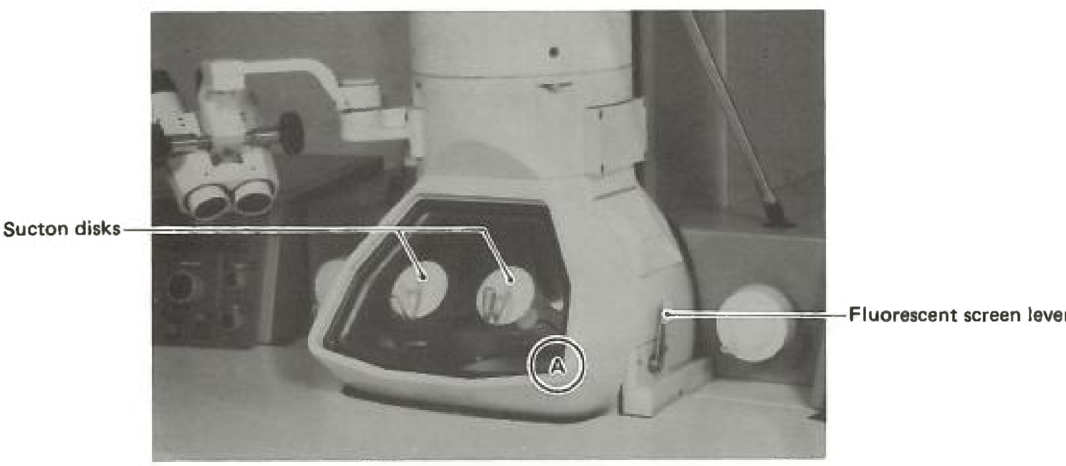


Fig. 6.2-1 Viewing chamber

3. While holding the small fluorescent screen bar with one hand, carefully remove the screen with the other (Fig. 6.2-2).
   Caution: Be careful when handling the screen as its fluorescent surface is easily scratched.
4. Carefully insert the new fluorescent screen with one hand while holding the screen bar with the other.

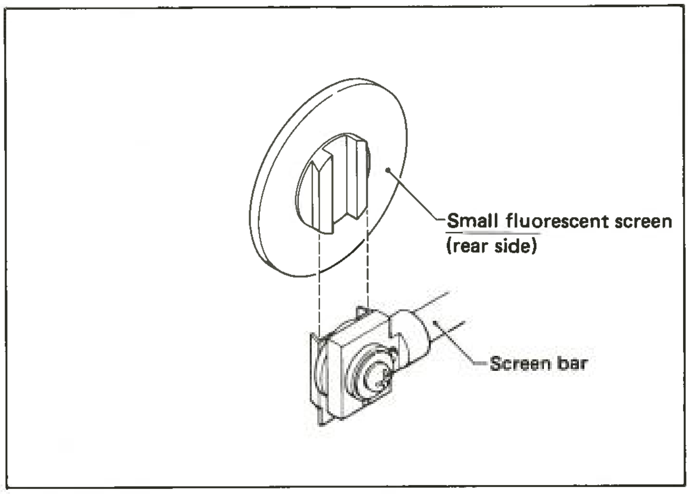


Fig. 6.2-2 Small fluorescent screen replacement

5. Replace the glass after making sure that the glass grounding spring (at A in Fig. 6.2-1) is properly set (Fig. 6.2-3), and the O-ring and its mating surface are free from lint.

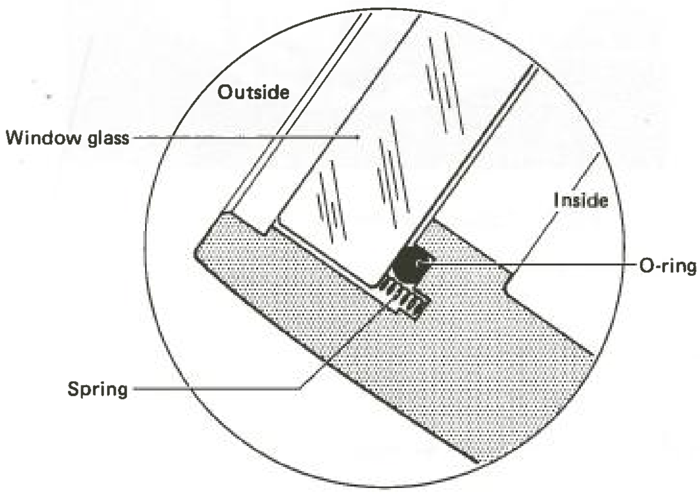


Fig. 6.2-3 Glass grounding spring

6. Close the camera chamber door, and while pressing the door, turn the door handle counterclockwise until it stops. Evacuation of the camera chamber commences. When the evacuation is completed, valve V3 automatically opens.

   Note: Valve action is shown on PAGE-3.

6.3 Freon gas replenishment

If the reading of the high voltage generating tank pressure gauge drops to below 0.4, replenish the tank with freon gas as follows:

1. Shut down the microscope.
2. Remove the cover from the high voltage generating tank. If a freon gas cylinder is not mounted on the top of the high voltage generating tank, proceed to Step 3. If a freon gas container is mounted on the tank, carry out Steps 5 and 6. (See Fig. 6.3-1.)

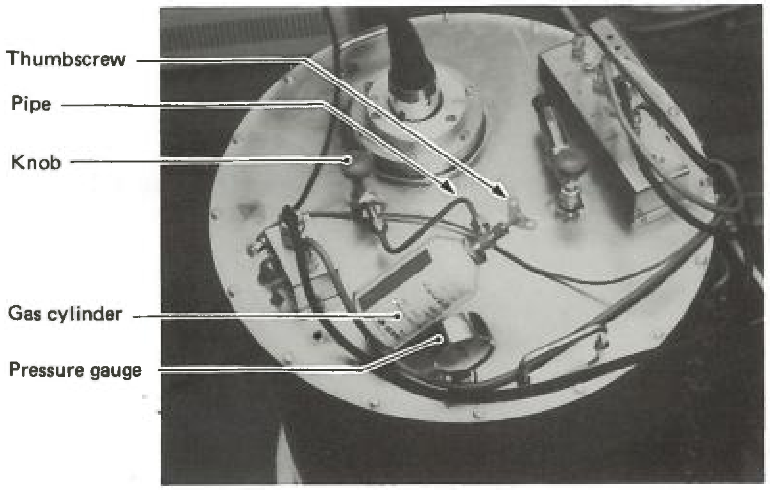


Fig. 6.3-1 Top view of high voltage generating tank

3. Attach the gas control valve (Fig. 6.3-2) to the freon gas cylinder.
   3a. Move the nut in the arrow's direction (Fig. 6.3-2) by turning it until it stops.
   3b. Turn the thumbscrew fully counterclockwise.
   3c. Screw the gas control valve fully into the gas cylinder and tighten the nut.
   3d. Turn the thumbscrew fully clockwise.
4. Connect the gas cylinder and high voltage generating tank with the pipe as provided, and tighten the two nuts with a wrench (Fig. 6.3-1).
5. Turn the knob and thumbscrew counterclockwise, and when the pressure gauge reading reaches 0.5, turn them fully clockwise.

   If the pressure gauge reading does not increase when the knob and thumbscrew are turned counterclockwise, turn the knob fully clockwise, then remove the gas cylinder and control valve, connect a new cylinder as

per Steps 3 and 4, and carry out Step 5.

6. Replace the tank cover.

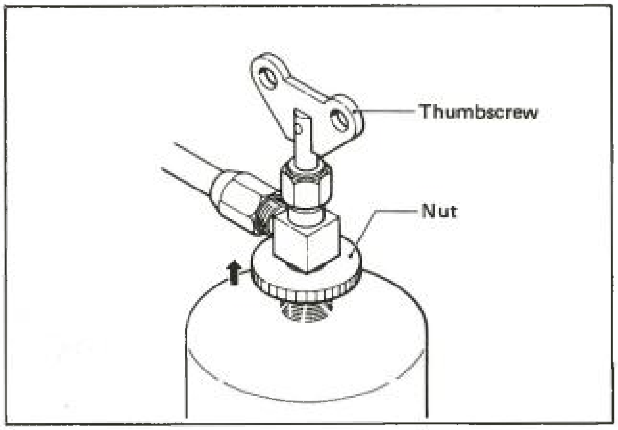


Fig. 6.3-2 Gas control valve

6.4 Oil rotary pump maintenance

6.4.1 Pump oil replenishment

If the oil level is below the ● guide mark on the pump box window, replenish supply as follows (Fig. 6.4-1):

1. Remove the oil supply port (exhaust port) cap by turning it counterclockwise.
2. Feed specified oil until the oil level is as shown in Fig. 6.4-1.
3. Replace the cap.

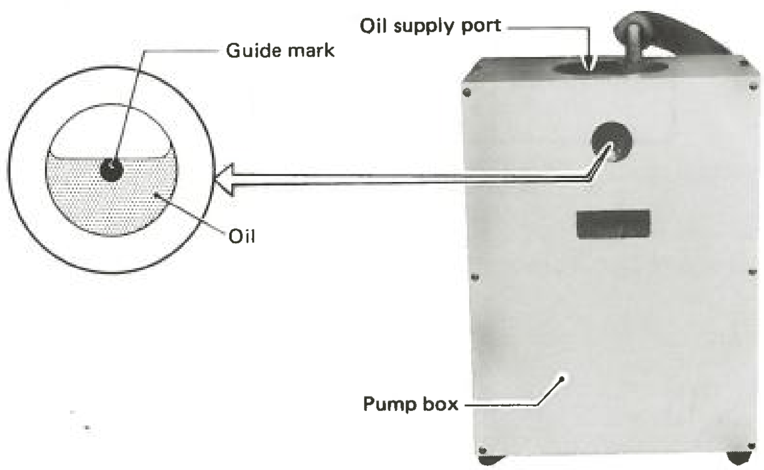


Fig. 6.4-1 Replenishing the oil rotary pump

6.4.2 Pump oil replacement

Long-term use of the oil rotary pump causes pump oil to gradually deteriorate (becomes discolored), which will adversely affect pump performance. Pump oil must be replaced every one or two years.

1. Shut down the microscope.
2. Remove the cover from the pump box.
3. Unscrew the drain plug to drain oil.
4. Tightly screw the drain plug and remove the oil supply port cap.
5. Feed specified oil until the oil level rises to within 10 mm of the level shown in Fig. 6.4-1, and replace the oil supply port cap.

   Note: More oil is fed in Step 8. The total amount of oil supplied will finally be about 1.5 ℓ.
6. Push the belt with fingers and make sure it can be deflected about 10 mm. If the belt tension is not proper, adjust the pump supporting nuts (Fig. 6.4-2). Then, after ascertaining that the motor pulley and pump

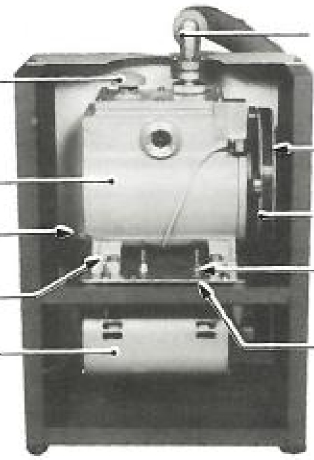


Fig. 6.4-2 Oil rotary pump

pulley are on the same vertical plane, tightly fasten the fixing nuts.

7. Replace the cover.
8. After starting up the microscope, feed oil in accordance with Sect. 6.4.1.

6.4.3 Belt replacement

If the belt breaks, the instrument shuts down automatically.

1. Remove the cover from the pump box.
2. Remove the bolts, tilt the pump and engage a new belt (Fig. 6.4-2).
3. After confirming that the motor pulley and pump pulley are on the same vertical plane, secure the pump with the bolts.
4. Push the belt with fingers and make sure it can be deflected about 10 mm. If the belt tension is not proper, adjust the pump supporting nuts (Fig. 6.4-2). Then, after confirming that the motor pulley and pump pulley are on the same vertical plane, tightly fasten the fixing nuts.
5. Replace the cover, and start up the microscope.

6.4.4 Vacuum rubber hose replacement

Vacuum rubber hoses will show cracks and where they bend will be pinched after prolonged use. Replace them in such cases. If hose removal is difficult, make a cut in the hose and pull it off; when making a cut, be sure not to damage the evacuation pipe; even the slightest scratch in the pipe will result in vacuum deterioration. When inserting a new hose, lubricate sparingly the inside of both ends of the hose with water or organic solvent (this will ease the insertion operation) and slide it onto the pipe. Be sure not to use grease instead of water or organic solvent; otherwise the hose may slip out of itself and the microscope will be damaged.

6.5 Turbomolecular pump oil replacement

The pump oil must be replaced when pump operation has exceeded 5,000 hours. Contact your nearest JEOL Service Center for assistance.

6.6 Silica gel replacement

A silica gel cylinder can be found when the evacuation pipe cover on the rear side of the column is removed. If the silica gel starts discoloring, replace it with a dried one.

6.7 Cleaning the column parts

After prolonged operation, the column interior becomes contaminated by electron beam bombardment and instrument performance is adversely affected. Accordingly, in order to ensure observation of excellent images at all times, clean (or replace) the contaminated parts periodically.

6.7.1 Precautions

a. When handling column parts, be sure to wear thin work gloves in order to prevent contamination by perspiration, etc., which could cause charging due to corrosion of the parts.

b. Avoid using metal tools, because even a slight scratch on a component part may adversely affect column vacuum and cause the electron beam to be improperly deflected.

c. Exerting force when inserting or removing parts may distort or damage them. Be specially careful when inserting or removing the pole pieces.

d. Prolonged exposure of the column parts to the atmosphere will cause corrosion of their surfaces. Disassembly, cleaning, and reassembly must be completed quickly.

e. When removing or fastening screws, nuts, etc., use the proper tools for them in order not to damage screw heads and threads.

f. Keep the O-rings and their mating surfaces free from scratches, dust, lint, etc. Even a slight scratch or fine dust will adversely affect the column vacuum. Be sure to use the specified types of vacuum grease as per Sect. 6.7.6.

g. When using organic solvent, select an adequately ventilated place without fire hazard, and do not allow prolonged contact with the skin.

6.7.2 Cleaning materials, tools, etc.

a. Cleaning liquid (organic solvent)

To remove grease, etc. and traces of metal polish. The cleaning liquid should be volatile, containing little impurity, preferably non-inflammable, and should have a high solution-forming rating (high cleaning power) and a high safety factor.

b. Fine grain metal polish

To remove encrustation and other extraneous matter having high adhesive properties. The polish should be easy to remove with organic solvent.

c. Gauze or rayon paper (crepe or gauze type)

To apply metal polish or cleaning solvent; should be of high quality and not release impurities when moistened with organic solvent.

d. Absorbent cotton

To clean scratched parts and important parts. By wrapping the cotton around a thin stick, it can also be used for cleaning difficult-to-get-at corners and recesses. The cotton should be of high quality.

e. Cotton swabs or toothpicks

To clean narrow places. Any commercially available (but untreated) product is suitable.

f. Sticks (about 5 mm dia.) or chopsticks

With absorbent cotton wrapped around them, they are used for cleaning the inside of cylindrical parts. Any commercially available (but untreated) product which is straight and round is suitable.

g. Beakers

To clean small parts in them. Should be made of stainless steel or aluminum, or enamel-coated. (Glass is not recommended as it is easily broken.)

h. Thin work gloves

To be worn when handling the internal parts of the column to prevent contamination and corrosion due to perspiration. Any commercially available cotton, nylon, or polyethylene gloves are suitable.

6.7.3 Cleaning methods

Cleaning method A (using cleaning liquid)

Application: Cleaning of lightly contaminated parts, not critical parts, and parts where metal polish is unsuitable (likely to affect microscope performance)

For flat surfaces, moisten a piece of gauze, rayon paper, or absorbent cotton with cleaning liquid (organic solvent), and rub the surface in question until it becomes clean. In the case of holes or the interior of cylindrical parts, use cotton swabs, or toothpicks or the like wrapped in absorbent cotton.

To remove oil, etc. from intricate or threaded parts, immerse the parts in a beaker of solvent. Replace the solvent when it becomes dirty. An ultrasonic cleaner is highly effective for cleaning extremely complicated parts. Immediately after removing the parts from the beaker of solvent, remove any traces of liquid with the hand blower.

Cleaning method B (using metal polish and then removing the polish with cleaning liquid)

Application: Cleaning of heavily contaminated parts (where metal polish usable)

For flat surfaces, apply a small amount of metal polish to a piece of gauze, rayon paper, or absorbent cotton, and rub the surface in question until it becomes clean. In the case of holes or the interior of cylindrical parts, use cotton swabs, or tooth picks or the like wrapped in absorbent cotton. Refrain from applying polish to intricate or threaded parts.

Avoid applying excessive force when rubbing the contaminated surfaces. To clean apertures, we recom-

mend the use of an absorbent cotton-wrapped cotton swab of the same size as the hole. Clean the holes by rotating the swab evenly. If this recommendation is unheeded, there is a possibility of pushing the hole out of shape.

Remove any traces of polish with cleaning liquid by repeating method A cleaning several times. If some polish remains, it will in itself become a contaminant, completely defeating the object of the task in hand. Finally, keep the cleaned parts covered until ready for reassembly.

Cleaning method C (heating in a vacuum evaporator)

Application: Cleaning of parts having a high melting point (tantalum or molybdenum foil, etc.)

By using the JEE Vacuum Evaporator, the apertures can be cleaned as follows (refer to the JEE Vacuum Evaporator Instructions):

1. Remove the bell-jar from the vacuum evaporator.
2. Mount the boat on the vacuum evaporator electrodes, using washers (Fig. 3.2-1) as shown in Fig. 6.7-1.

JEE vacuum evaporator

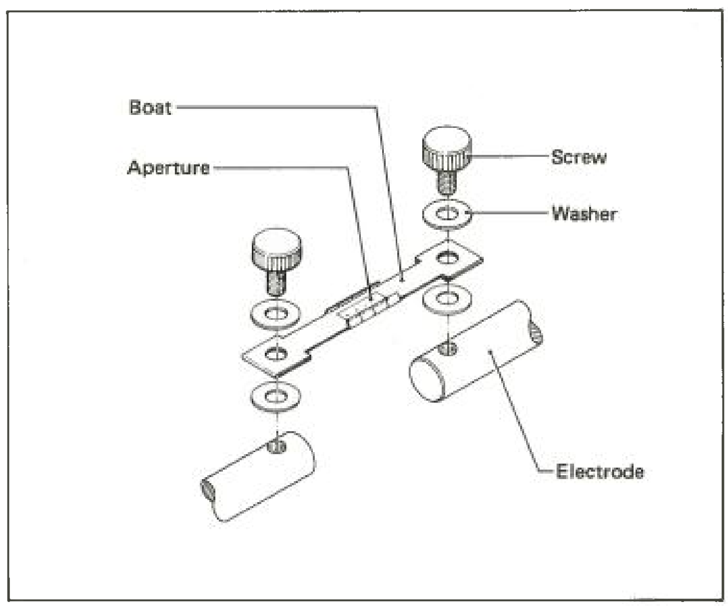


Fig. 6.7-1 Aperture cleaning

3. Replace the bell-jar, and pump the jar to better than 1×10^{-4} Torr (1.3×10^{-2} Pa).
4. Heat the boat by passing a current of 30 A for about one minute.
5. Allow three minutes after heating before breaking the bell-jar vacuum.
6. Break the bell-jar vacuum and remove the bell-jar.

7. Place an aperture (only one aperture at a time) in the boat.

   Caution: Use tweezers to handle the aperture, and be sure not to scratch or deform it.

8. Repeat Steps 3 to 6.
9. Remove the aperture.

6.7.4 Parts requiring cleaning

Section	Component part	Cleaning method	Cleaning frequency
Wehnelt assembly	Aperture holder	B	When changing the filament
	Aperture disk	B	
	Cap	B	
Anode	Anode	A	Every 6 months
Condenser lens aperture assembly	Aperture foil	C	
	Aperture holder	A	
Objective lens aperture assembly	Aperture foil	C	
	Aperture holder	A	
Field limiting aperture assembly	Aperture foil	C	
	Aperture holder	A	

Note: See Sect. 6.7.3 for the cleaning methods.

6.7.5 Removing and cleaning parts

6.7.5a Wehnelt assembly and anode

1. Remove the Wehnelt assembly as per Sect. 6.1 and anode. The anode can be removed by turning it counterclockwise.
2. Disassemble the Wehnelt cap (Fig. 6.7-2).

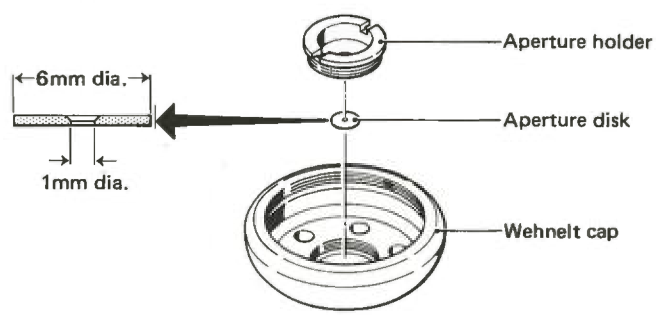


Fig. 6.7-2 Exploded view of Wehnelt cap

3. Clean the aperture holder, aperture disk, Wehnelt cap and anode using method B.
   Caution: Do not touch the insulator and anode chamber inner wall.
4. Reassemble the Wehnelt cap, and replace the Wehnelt assebmly and anode.
   Caution: Make sure that the aperture disk has been horizontally set in the original place. Be careful not to place the disk upside-down.
5. Evacuate the anode chamber in accordance with Sect. 6.1.

6.7.5b Aperture assemblies

1. Admit air into the column (see Sect. 6.7.7).
2. Insert the condenser lens, objective lens, and field limiting apertures into the electron beam path by operating the levers of the respective aperture assemblies.
3. Remove the fixing screws of the aperture assemblies, and slowly draw out the assemblies (Fig. 6.7-3).
4. Remove the aperture foil from each aperture holder with tweezers (Fig. 6.7-4).
5. Clean the aperture foils using cleaning method C, and the aperture holders using method A.
6. Reassemble and replace the aperture assemblies.
7. Evacuate the column (see Sect. 6.7.7).

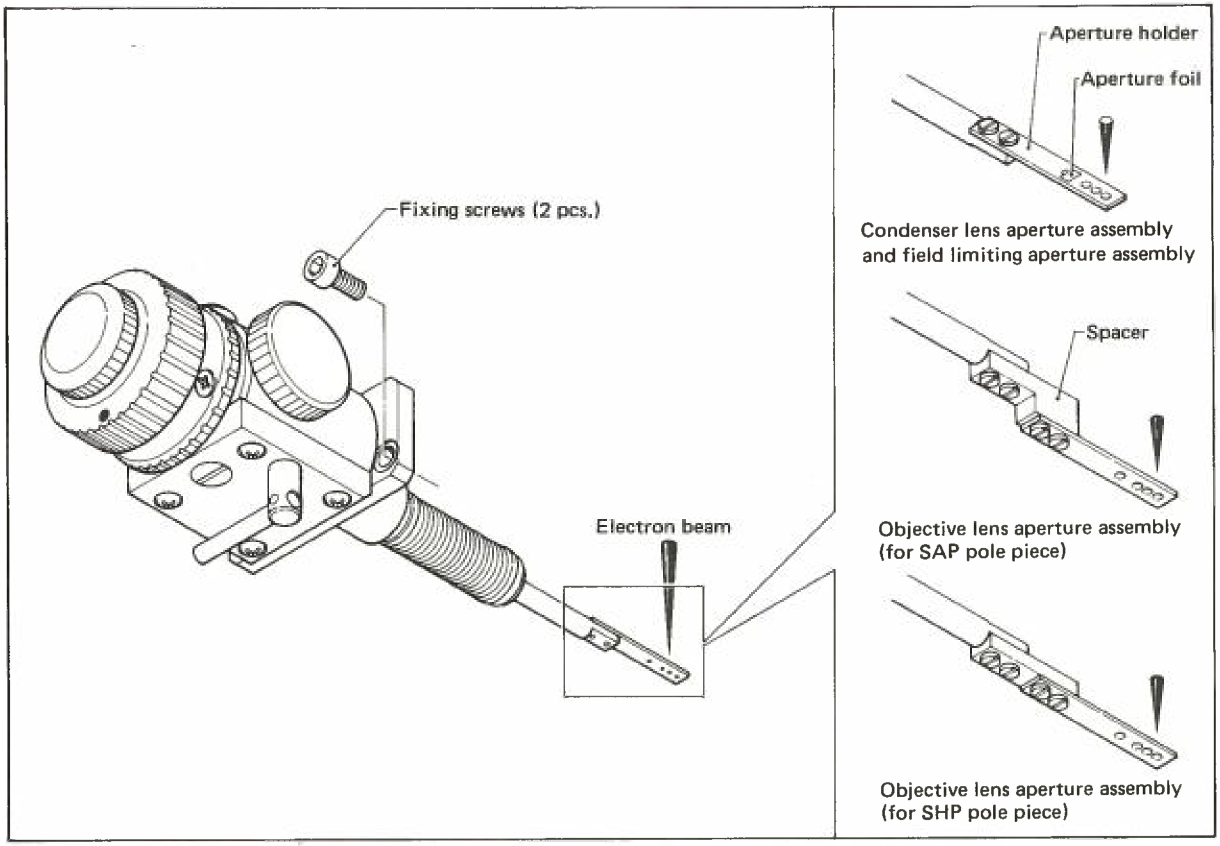


Fig. 6.7-3 Aperture assemblies

Condenser lens aperture : 200, 300, 400 μm
Objective lens aperture : 20, 50, 80 μm
Field limiting aperture : 20, 100, 300 μm
} Aperture foil

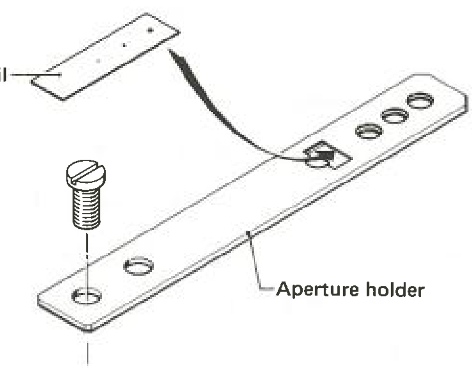


Fig. 6.7-4 Aperture foil and aperture holder

6.7.6 Use of vacuum grease

Two types of vacuum grease, Fomblin and Apiezon, are provided. Be sure to use Fomblin on the O-rings within the enclosed section in Fig. 6.7-5, and on attachments to be installed in the same section. Use Apiezon on other O-rings.

As a rule, apply grease only to movable parts and difficult-to-remove/replace parts. The amount of grease applied must be as slight as possible.

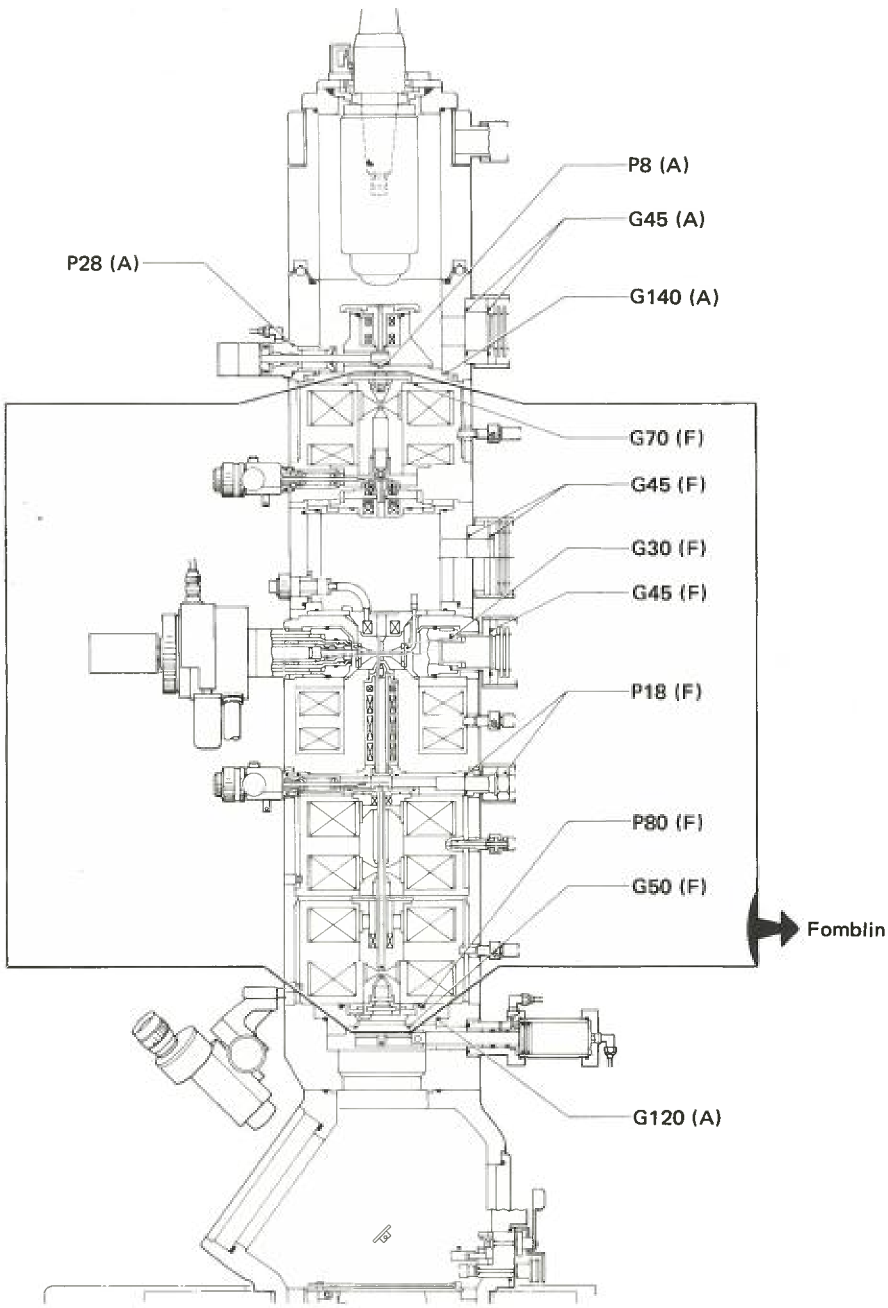


Fig. 6.7-5 Use of vacuum grease

6.7.7 Breaking the column vacuum and re-evacuation

6.7.7a Admitting air into the column

1. Set the FILAMENT knob (L1-2) to OFF, and release the HT button (L1-6).
2. Remove the specimen holder, and remove all the apertures from the electron beam path.
3. Raise the anticontamination device cooling trap to room temperature (see Sect. 5.8.2).

   Caution: If air is admitted into the column with the cooling trap (in the specimen chamber) in the cooled state, moisture will condense into water droplets and ice will form on the trap and adjacent parts, causing rust.
4. Confirm that the PI2 and PI3 values (displayed on PAGE-3) are both 150μA or less. If both values or either one of them is larger than 150μA, evacuate the anode and camera chambers until both values decrease to 150μA or less.
5. Depress the COL AIR button (L2-5). Air is now admitted into the anode chamber and column (except the viewing chamber).
6. If air is to be admitted also into the viewing chamber and camera chamber, turn the camera chamber door handle clockwise as far as it will go.

6.7.7b Re-evacuating the column

1. Confirm that all the parts removed have been replaced.
2. Release the COL AIR button (L2-5). The column is now evacuated. When the electron gun has not been hoisted by the lift, the anode chamber is also evacuated.
3. If the viewing chamber and camera chamber are also to be evacuated, close the camera chamber door and turn the door handle counterclockwise until it stops.

6.8 Objective lens pole piece exchange

1. Admit air into the column (see Sect. 6.7.7).
2. Turn off the ALIGN: COND2 switch (Fig. 6.8-1).

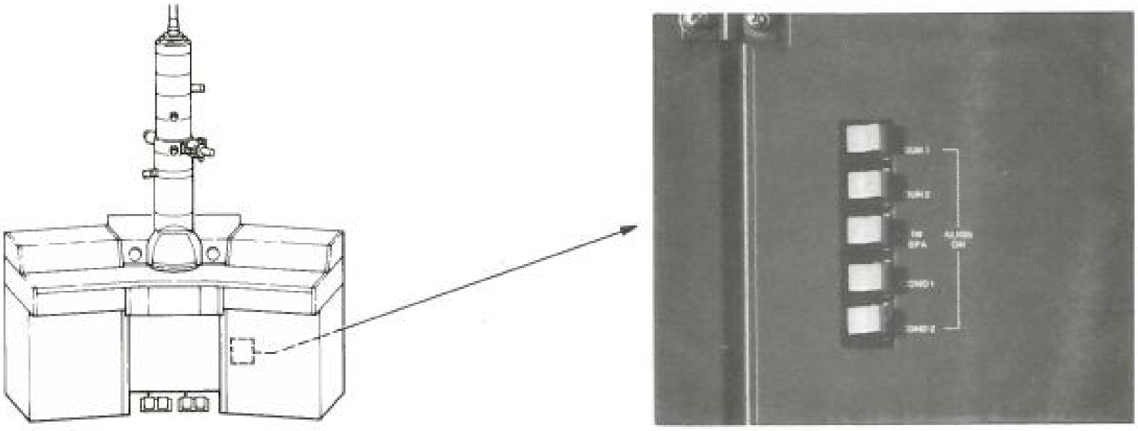


Fig. 6.8-1 ALIGN switches

3. Disconnect the CLA2 cable (Fig. 6.8-2).
4. Remove the nut, unscrew the left-side blank plate fixing screws, and then carefully remove the plate without applying force.

   Caution: Force must not be applied to the connector.

5. Loosen the beam deflector coil fixing screws, and remove the beam deflector coil.
6. Remove the objective lens aperture assembly.
7. Manipulate the specimen selector so that the specimen number indicator pin is fully moved to 2 (Fig. 6.8-3).
8. After confirming that the OBJ button switch (L2-9) is on, screw the OL pole piece setting tool (Fig. 3.2-3) gently into the objective lens pole piece (Fig. 6.8-4), and release the OBJ button (L2-9).
9. After confirming that the specimen holder has been removed, carefully draw out the pole piece straight up. Before removing the pole piece, note its direction so as to be able to replace the pole piece exactly as it was before removal.

   Caution: Be very careful when handling the objective lens pole piece. Avoid rotating the pole piece in the yoke or tilting the pole piece (even slightly) when withdrawing it. This is of utmost importance as the objective lens pole piece is the most critical part of the microscope, and scratches, etc., however slight, adversely affect microscope performance.

10. Screw the OL pole piece setting tool into the SAP or SHP objective lens pole piece for use (about 2.5 turns).

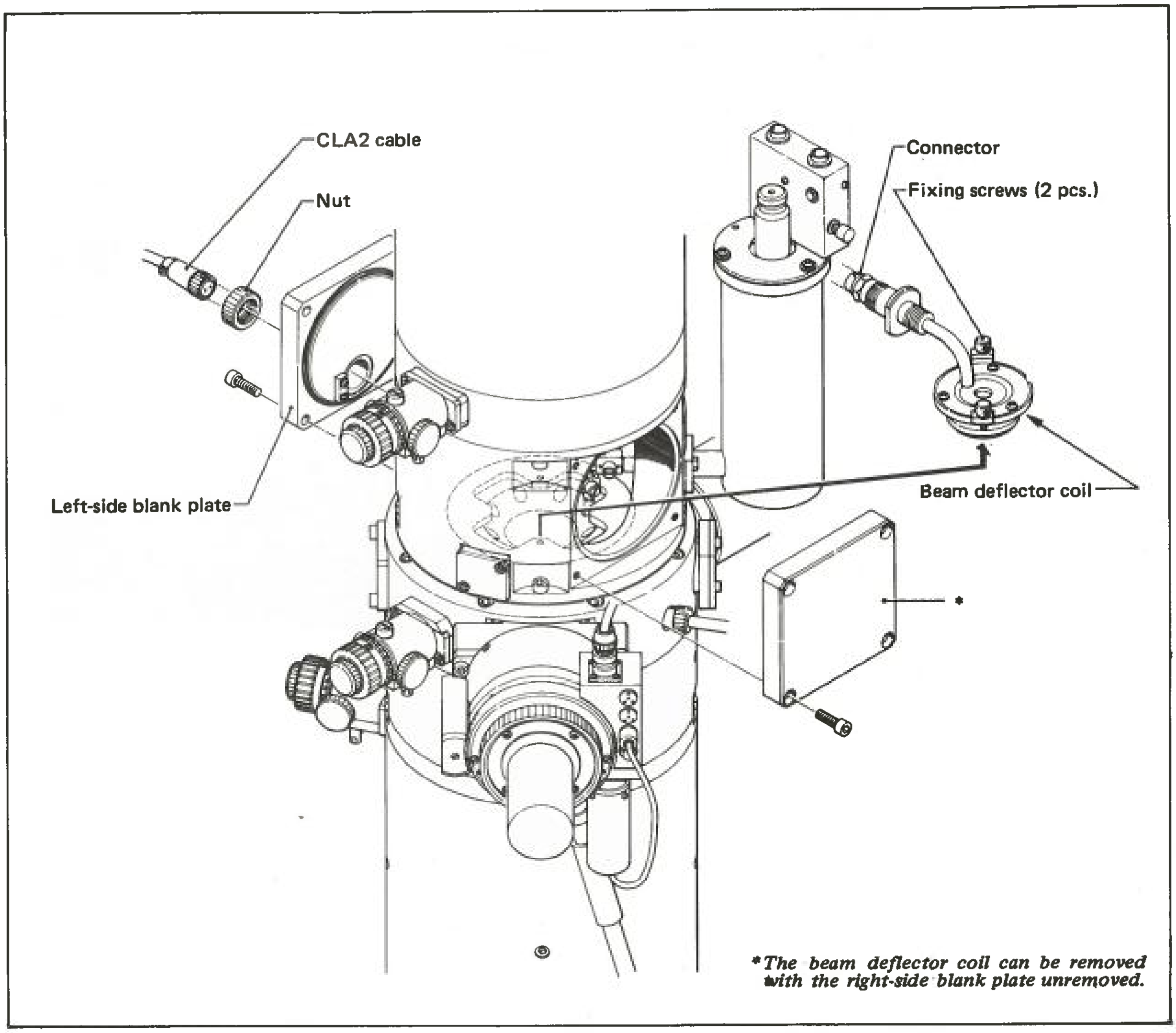
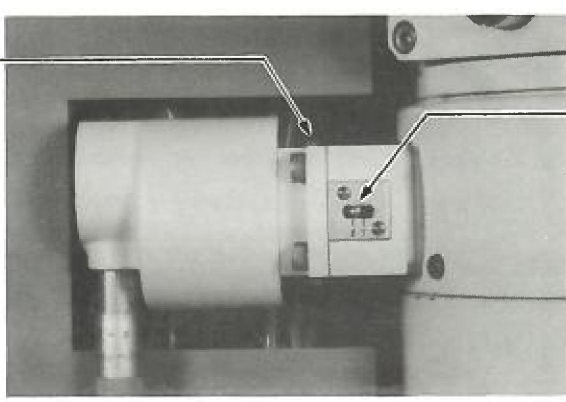
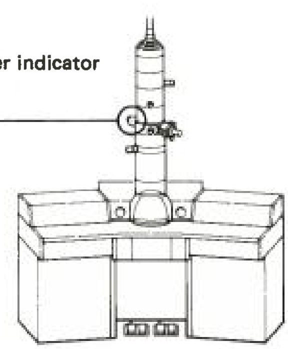


Fig. 6.8-2 Removing the beam deflector coil





11. Carefully insert the pole piece into the objective lens yoke, making sure that the pole piece is properly oriented, i.e., the pole piece direction is the same as it was before removal.

    Caution: Since the objective lens pole piece is the most critical part of the microscope, take special care when handling the pole piece. Never rotate the pole piece in the yoke. If it is desired to change the orientation, lift the pole piece out of the yoke, orientate it as required, and reinsert the pole piece. Also, when inserting the pole piece, keep it perfectly upright, i.e., avoid tilting the pole piece.

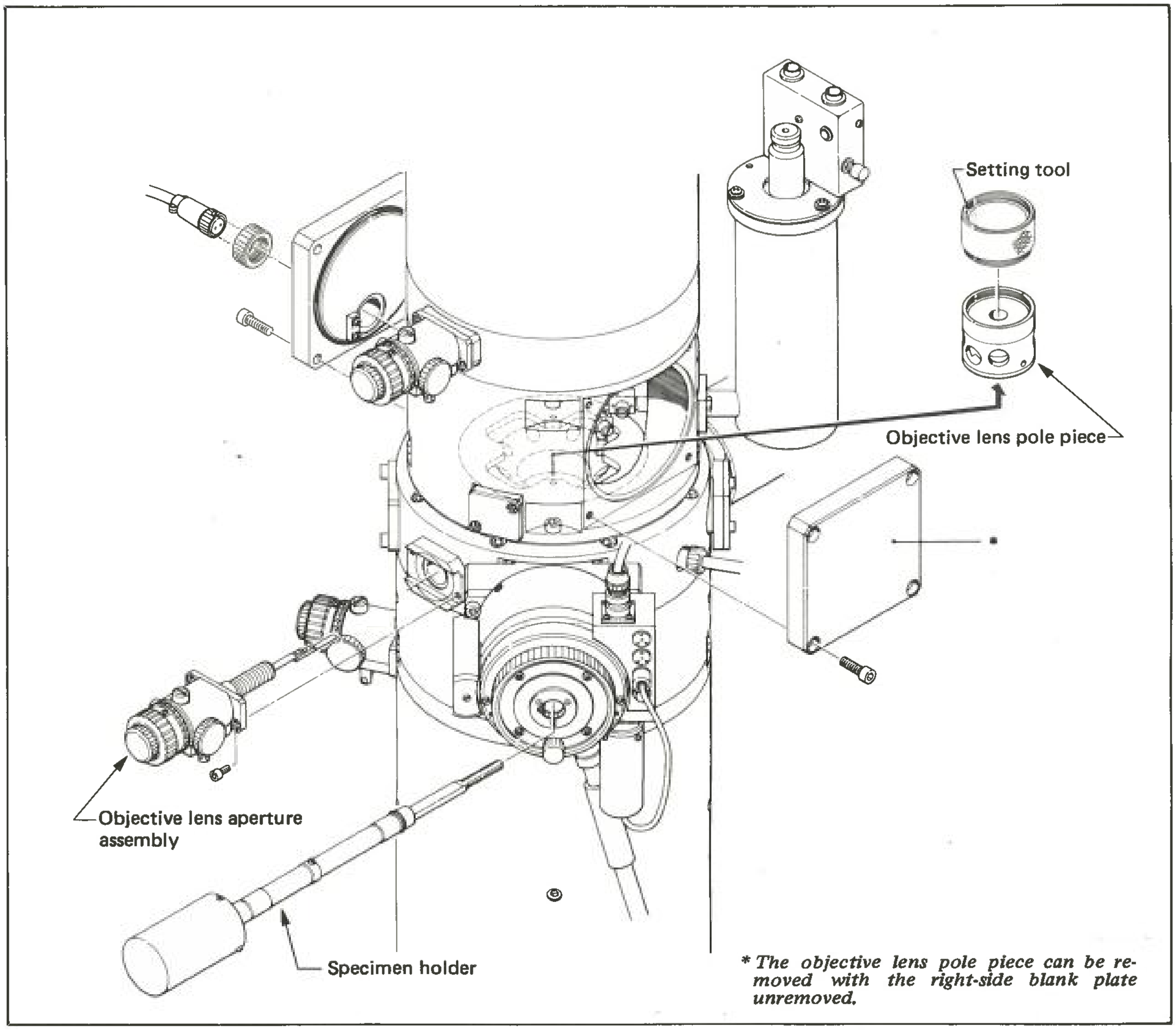


Fig. 6.8-4 Removing the objective lens pole piece

12. Make sure that the center of the aperture insertion hole in the pole piece (Fig. 6.8-5) is properly aligned with the center of the hole in the objective lens, then depress the OBJ button (L2-9).
13. Remove the tool, and replace the beam deflector coil.
14. Replace the left-side bland plate, and secure the connector with the nut.
15. Connect the CLA2 cable, and turn on the ALIGN: COND2 switch.
16. Replace the objective lens aperture assembly, and re-evacuate the column (see Sect. 6.7.7).
17. Set the X-tilt angle limiting screws to 60° or 25° according to the pole piece in use (SAP or SHP) (see Sect. 5.2.6), and accord the pole piece name displayed on PAGE-1 with the pole piece in use with the MAG key (KB-1).
18. Manipulate the specimen selector so as to return the specimen number indicator pin to the original position as per Sect. 5.7.6, Step 7.

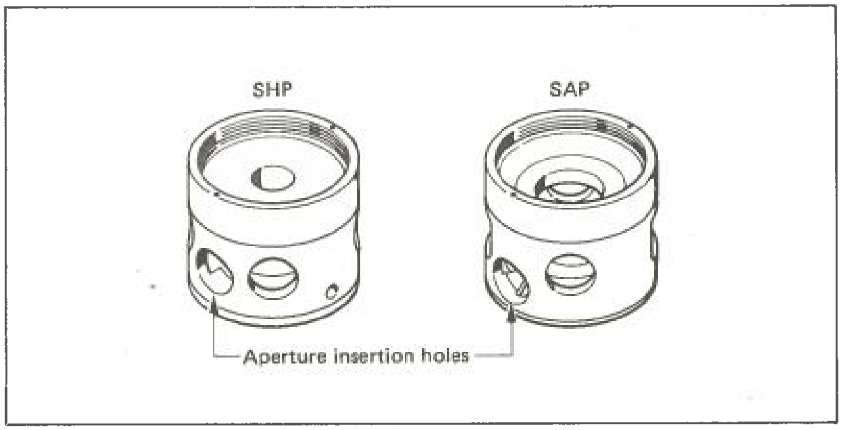


Fig. 6.8-5 Objective lens pole piece

6.9 Baking out the column

Specimen contamination can be considerably reduced by heating the column and freeing adsorbed gas molecules from the column interior walls. Bake out of the column interior is recommended if it has been exposed to air for a long time.

1. Display 120 kV on PAGE-1 using the ACCEL VOLTAGE switch (L1-5).
2. Turn the FILAMENT knob (L1-2) to OFF and release the HT switch (L1-6).
3. After confirming that the LENS POWER SUPPLY switch (L2-2) is set at ON, depress the BAKE OUT button (L2-7).

   Caution: Do not tamper with the switches and controls on the control panels until the BAKE OUT button (L2-7) is released. If inadvertently tampered with, release the BAKE OUT button (L2-7) and re-depress it.

4. Close the lens cooling water valve (Fig. 6.9-1).

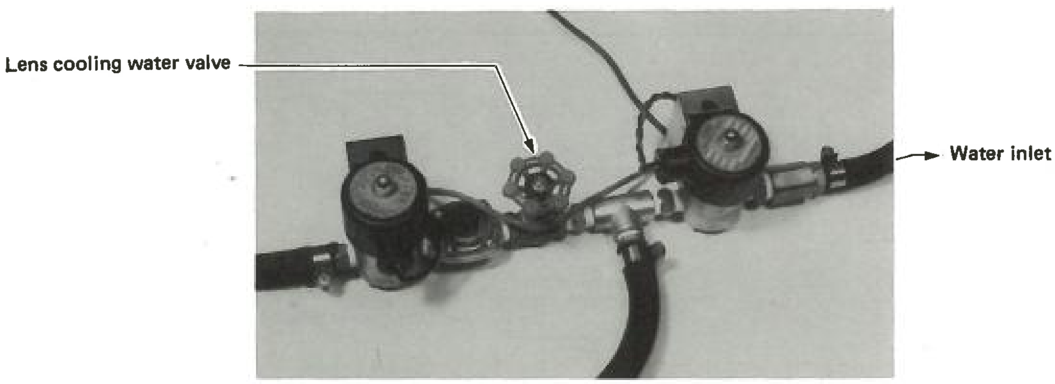


Fig. 6.9-1 Lens cooling water valve

5. Wait about 10 hours.
6. Turn off the LENS POWER SUPPLY and BAKE OUT switches (L2-2, L2-7).
7. Wait about one hour more.
8. Fully open the lens cooling water valve, then turn on the LENS POWER SUPPLY switch (L2-2).

6.10 Troubleshooting

6.10.1 Concerning start-up

6.10.1a When impossible to start up

Cause	Remedy
a. Turned off circuit breaker *Note: The breaker is in the power supply console.*	Switch off the main power and set the breaker to ON. Then start up the instrument after switching on the main power.
b. Broken fuse F4 (see Subject. 6.10.5).	Replace.

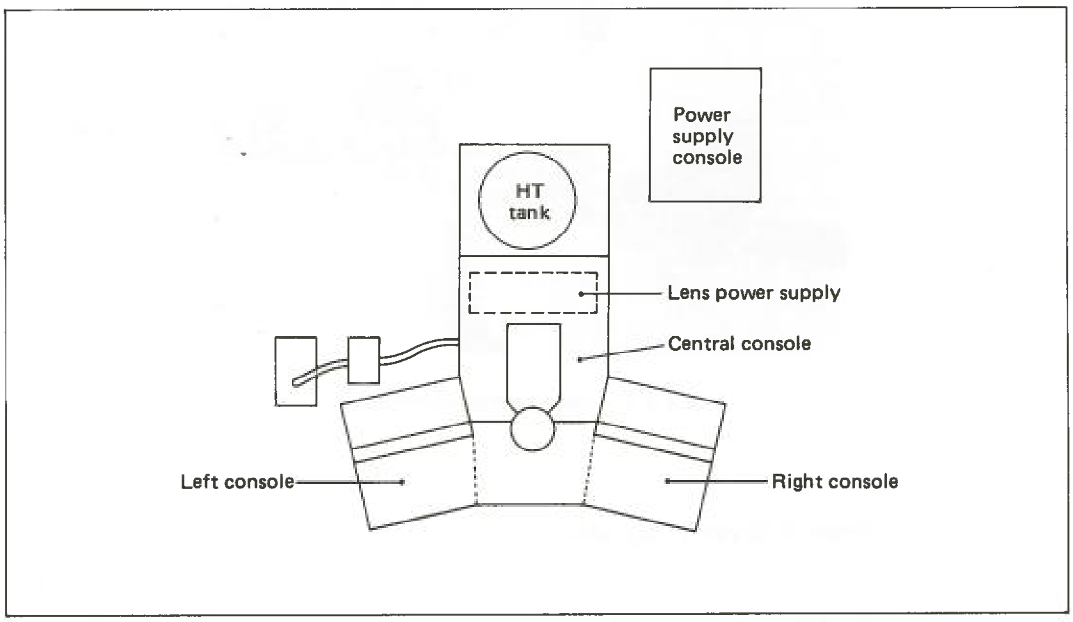


Fig. 6.10-1

6.10.1b When the instrument stops automatically some time after start-up

Cause	Remedy
a. Insufficient water pressure (in this case the instrument stops in 2 or 3 seconds)	Increase the pressure.
b. Broken Pirani gauge head (in this case the instrument stops in 2 or 3 seconds) *Note: Four heads are used. To ascertain which one is broken, shutdown the instrument, remove the cable from one of the four heads, and do a continuity test between head pin 1 and 2, and between 3 and 4 (Fig. 6.10-2).*	Replace. Break the column and anode chamber vacuum before replacing Pirani gauge heads PiG1 and 2, and the camera chamber vacuum before replacing PiG3. In the case of PiG4, shut down the instrument before replacing it, i.e. break the vacuum reservoir vacuum.
c. Broken rotary pump belt (in this case the instrument stops in 30 seconds)	Replace (see Subsect. 6.4).
d. Insufficient TMP rotation speed (in this case the instrument stops in 20 minutes) *Note: The rotation speed is indicated on the ion pump power supply control panel (Fig. 6.10-3).*	See Subsect. 6.10.1c.
e. Pirani gauge head PiG4 reading (indicated on PAGE-3 on the CRT) is more than 220 μA after 20 minutes from start-up (in this case, the instrument stops in 20 minutes).	Contact your nearest JEOL representative.
f. The radiator fan in the power supply console is broken (in this case the instrument stops when the radiator temperature reaches 90°).	Contact your nearest JEOL representative.
g. Compressed air pressure less than 3.2 kg/cm^2.	Contact your nearest JEOL representative.

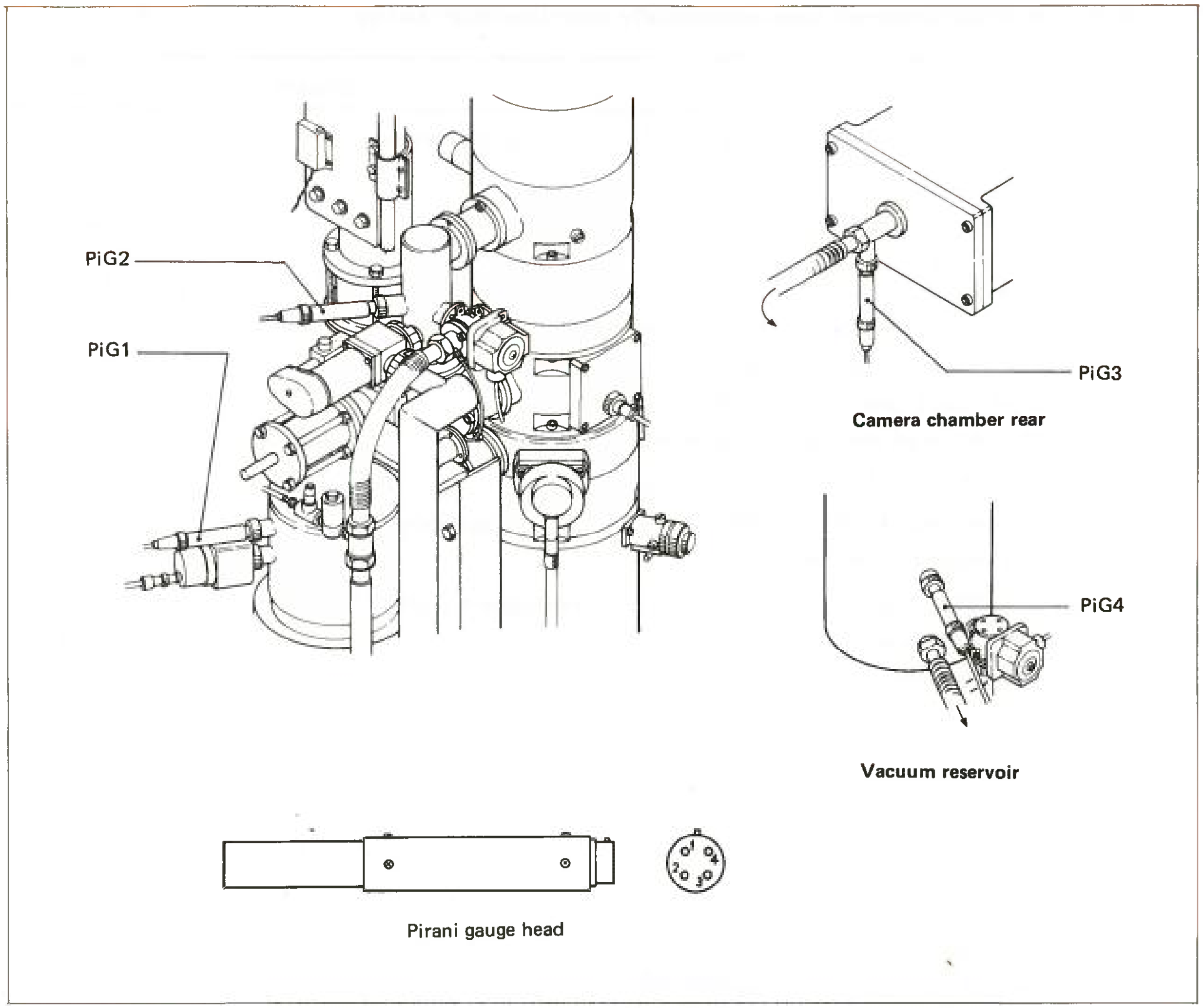


Fig. 6.10-2

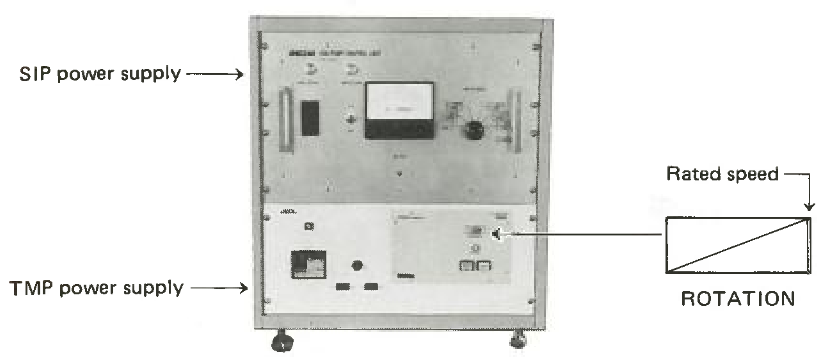


Fig. 6.10-3

6.10.1c When the turbomolecular pump rotation speed is less than the rated speed (when the EM-TMP is used)

Cause	Remedy
a. Broken fuse F6 (see Subject. 6.10.5)	Replace.
b. A broken TMP fuse *Note: The TMP fuses are in the TMP power supply console (Fig. 6.10-3).*	Replace.

6.10.1d When the READY lamp does not light up

Cause	Remedy
a. Function of the ion pump imperfect (when the EM-SIP is used)	See Subsect. 6.10.1e.
b. Disengaged HV cable electron gun side	Switch off the HV and connect the cable to the electron gun.
c. Closed anode chamber airlock valve V2	Evacuate the anode chamber and wait until V2 opens.

6.10.1e When the ion pump functions improperly (when the EM-SIP is used)

Cause	Remedy
a. Contaminated pump interior and/or fatigued pump elements	Contact your nearest JEOL representative.
b. Broken fuse *Note: The fuse appears when the rear panel of the SIP power supply (Fig. 6.10-3) is removed.*	Replace.
c. Turned off HIGH VOLTAGE and PROTECTION switches on the SIP pump power supply (Fig. 6.10-3)	Turn both switches on.

6.10.2 Concerning the electron beam

6.10.2a When no electron beam appears on the screen

Cause	Remedy
a. No electron beam is generated.	See Subsect. 6.10.2b.
b. The specimen number indicator is pointing between 1 and 2.	Set the indicator to 1 or 2.

6.10.2b When no electron beam is generated, i.e. the BEAM CURRENT meter reading increases less than 3 μA when the FILAMENT knob on control panel L2 is turned clockwise

Cause	Remedy
a. Unlit READY lamp	See Subsect. 6.10.1d.
b. Closed viewing chamber airlock valve V3	Evacuate the camera chamber and wait until V3 opens.
c. Insufficient BIAS MODE value (control panel L1)	Set to 70~80.
d. Insufficient distance between the Wehnelt cap and filament tip	Set to 1.0 mm (see Subsect. 6.1).
e. Burnt out gun filament	Replace (see Subsect. 6.1).

6.10.3 Concerning the specimen

6.10.3a When a focussed image cannot be obtained

Cause	Remedy
a. Improper Z control knob setting	Carry out the tilt axis alignment (see Subsect. 5.9).

6.10.3b When the specimen can not be tilted

Cause	Remedy
a. Motor and goniometer are disengaged.	Make the lamp light up by pulling the motor towards you.
b. The X-TILT knob on the GONIO CONTROL (control panel L1) set to 0	Set to 4~6.

6.10.3c When the end of the specimen image cannot be shifted to the screen center

Cause	Remedy
a. Improper specimen selector setting	Set the selector so that the entire field of view can be seen in the screen center (see Step 7, Subsect, 5.2.6).

6.10.4 Voltage checking

6.10.4a Power supply console (Fig. 6.10-1)

The various voltages, as listed below, can be measured by connecting a volt meter to the checking terminals located behind the front door.

Voltage	Related fuse number
+15 V, CAMERA	F33
−15 V, CAMERA	F34
+15 V, CARD	F29
−15 V, CARD	F30
+5 V, CARD	F19, 20
+24 V, VALVE	F3

6.10.4b Central console (Fig. 6.10-1)

The various voltages, as listed below, can be measured by connecting a volt meter to the checking terminals located behind the left panel.

Voltage	Related fuse number
+90 V, lenses	F17, 18
+5 V, shutter	F31
−15 V, lenses	F27
+5 V, lenses	F26
+15 V, lenses	F25
+15 V, beam deflectors	F28
−15 V, beam deflectors	F16
+5 V, beam deflectors	F15

6.10.4c PAGE-4, 5, 6 (on the control panel CRT)

The reference voltages of all the lenses, stigmators and beam deflectors are shown on the CRT. The standard voltages are listed below.

Note: These voltages are for 120 kV. Multiply the listed voltages by 0.90, 0.80, 0.69 and 0.56 for 100, 80, 60 and 40 kV respectively.

Reference voltages for the lens currents (displayed on PAGE-4)

Lens	Measuring condition	Voltage
CL1	At 5,000×, SPOT SIZE knob to 1	1.5
CL2	At 5,000×, CL2 current maximized with the BRIGHTNESS knobs	8.2
OL	At 5,000×, OL current maximized with the OBJ FOCUS knobs	8.4
OM	At 3,000×	7.1
PL	At 5,000×	7.4 ~ 7.5
IL3	At 5,000×	5.4 ~ 5.5
IL2	At 1,000,000×	6.9 ~ 7.0
IL1	At 1,000,000×	7.3 ~ 7.4

Reference voltages for the deflector coil currents (displayed on PAGE-5)

Coil	Measuring condition	Voltage
GUN 1	Current maximized with the GUN ALIGN: X knobs	±5.0 ~ 5.1
	Current maximized with the GUN ALIGN: Y knobs	±4.5 ~ 4.7
GUN 2	Current maximized with the GUN ALIGN knobs	±4.0 ~ 4.2
SPA	SPOT SIZE knob to 1	±0 ~ 0.03
CLL1	The BRIGHT TILT button depressed, the DEF knobs set to midway, current maximized with the SHIFT knobs	±0.1 ~ 0.3
CLA2	The BRIGHT TILT button depressed, current maximized with the DEF knobs	±0.6 ~ 0.8
IS1	The IMAGE SHIFT button depressed, current maximized with the DEF knobs	±3.3 ~ 3.5
IS2	The IMAGE SHIFT button depressed, current maximized with the DEF knobs	±0 ~ 0.02
PLA	The DIFF button depressed, current maximized with the PROJ ALIGN knobs	±3.8 ~ 3.9

Reference voltages for the stigmator coil currents (displayed on PAGE-6)

Coil	Measuring condition	Voltage
COND	The COND STIG button depressed, current maximized with the DEF knobs	±7.8 ~ 8.2
OBJ	The OBJ STIG 1 or 2 button depressed, current maximized with the DEF knobs	±8.5 ~ 9.0
INT	The DIFF button depressed, current maximized with the INT STIG knobs	±7.0 ~ 8.0

6.10.5 Fuses and corresponding circuits

6.10.5a Inside the power supply console

F. No.	Rating	Corresponding circuit, pump, etc.
1	2 (A)	Card rack cooling fan, Penning gauge
2	5	AC 100 V outlets
3	1	For attachments use
4	1	Start-up circuit
5	10	Transformer 3 (F19 ~ 34 are related)
6	5	Oil rotary pump
8 9	5 5	Oil diffusion pumps (supplied to order)
10	20	Transformer 2 (F11 ~ 18 are related)
11	5	HT UNIT, +75 V
12	1	HT UNIT, +5 V
13	1	HT UNIT, +15 V
14	1	HT UNIT, −15 V
15	10	LENS UNIT, +15 V, deflectors
16	10	LENS UNIT, −15 V, deflectors
17 18	15 15	LENS UNIT, +90 V, lenses
19 20	15 15	CARD UNIT, +5V
21 22	15 15	Solenoid valves, +24 V
23	0.5	Solenoid valves, −5 V
24	5	Solenoid valves, +5 V
25	2	LENS UNIT, +15 V, lenses
26	2	LENS UNIT, −15 V, lenses
27	3	LENS UNIT, +5V, lenses
28	3	LENS UNIT, +5 V, deflectors

F. No.	Rating	Corresponding circuit, pump, etc.
29	10	CARD UNIT, +15 V
30	10	CARD UNIT, –15 V
31	3	LENS UNIT, +5 V, shutter
32	2	PRINTER UNIT (supplied to order), –30 V
33	3	CAMERA UNIT, +15 V
34	3	CAMERA UNIT, –15 V

6.10.5b Camera chamber

A fuse for the motor is located behind the left door of the chamber.

6.10.6 Self-diagnostic function

When starting up and when depressing the C H E C K RETURN keys on the keyboard, whether the bus lines of each interface PC board are normal is displayed on the CRT. If all the bus lines are normal, "NO PB ERROR" is displayed; otherwise a name of the board is displayed on the CRT. The following PC boards are diagnosed:

1. DEF PB
2. LENS PB
3. LENS PB, DEF LENS ITF PB
4. DEF PB, DEF LENS ITF PB
5. CAMERA ITF PB
6. HT VAC ITF PB
7. AD CONV PB
8. LEFT PANEL ITF PB
9. RIGHT PANEL ITF PB
10. FC ITF PB (supplied to order)
11. IRT KEY BOARD ITF PB
12. PRINTER ITF PB (supplied to order)

Notes: 1. *No. 1 is located on the front panel of the right console, No. 2 is located on the lens power supply in the central console, and No. 3 ~ 12 are inserted in the card rack located behind the right console rear side (Fig. 6.10-1). The lens power supply can be pulled out of the console left side.*

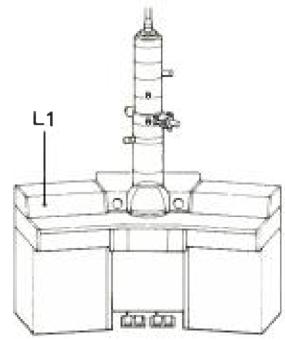
2. *No. 3 means the lens side circuit of the DEF LENS ITF PB is not normal, and No. 4 means the deflector side circuit of the PB is not normal.*

FLOWCHARTS

Startup

(Sect. 5.2.1)

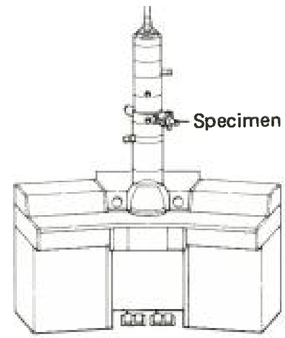
Cooling water tap · Open
↓
Distribution board switch · On
↓
POWER (L1) · · · · · · · · · · · · · · · · · · · START (5 sec) → ON
↓
READY (L1) · · · · · · · · · · · · · · · Wait until the lamp lights up



Shutdown

(Sect. 5.2.12)

FILAMENT (L1) · OFF
HT (L1) · OFF
Specimen holder · Remove
POWER (L1) · OFF
↓ Wait 10 minutes
Cooling water tap · Close
↓
Distribution board switch · Off



Routine operation (method C)

(Sect. 5.4)

Startup

↓

READY (L1) ··················· Check the lamp is on → Use of anticontamination device (Sect. 5.8)

↓

HT (L1) ································· Press

↓

BEAM CURRENT (L1) ······· Wait until reading stabilizes

Accelerating voltage (kV)	BEAM CURRENT reading
40	23 – 24
60	35 – 36
80	47 – 48
100	58 – 60
120	70 – 73

↓

Specimen and apertures ········· Remove from beam path

MAG2 (R1) ························ Press (5,000×)

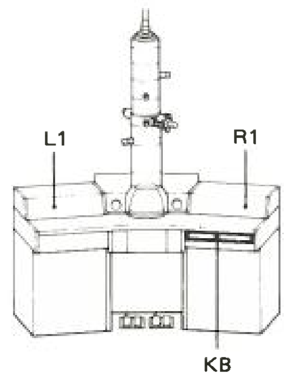
↓

FILAMENT (L1) ··················· Stopper position

↓

BEAM CURRENT (L1) ··········· The reading increased

- YES → Illumination appears on the screen when BRIGHTNESS (L1) is turned
- NO → Finding the electron beam → Focus illumination on the screen center with BRIGHTNESS (L1) and SHIFT (L1, R1)



Illumination appears on the screen when BRIGHTNESS (L1) is turned

- YES → Focus illumination on the screen center with BRIGHTNESS (L1) and SHIFT (L1, R1)
- NO → Finding the electron beam → Focus illumination on the screen center with BRIGHTNESS (L1) and SHIFT (L1, R1)

Focus illumination on the screen center with BRIGHTNESS (L1) and SHIFT (L1, R1)

↓

A L I G N RETURN (KB) ················ Press

1 (KB) ································· Press

↓

Carry out STEP-4

↓

Insert specimen for alignment

↓

```
** STEP- 4 **

INSERT & CENTER COND APERTURE
STIGMATE BEAM USING [illegible]

 COND STIG X5000

     NEXT     HIT RET
```

```
** STEP-10 **

CORRECT VOLTAGE CENTER
USING COND [illegible]

HT WOBBLER    25%

NEXT     HIT RET
```

```
** STEP-11 **

INSERT & CENTER OBJ APERTURE

DIFF  60 0cm

NEXT     HIT RET
```

Carry out STEP-8

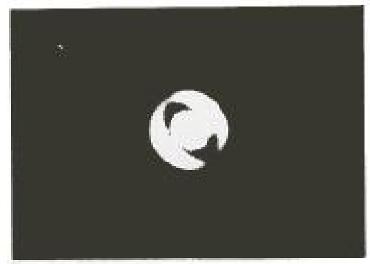
Carry out STEP-10

Carry out STEP-11

BRIGHT TILT (L1) · Off

Focus illumination with BRIGHTNESS (L1)

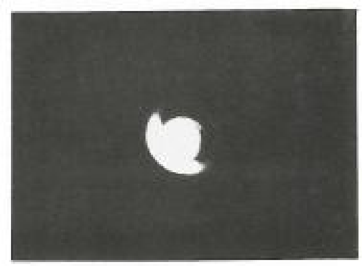
Obtain filament image with FILAMENT (L1)



Filament image is symmetrical

YES

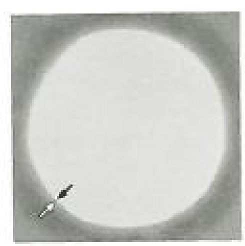
NO



Make filament image symmetrical with GUN ALIGN: TILT (R2)

Turn FILAMENT (L1) until filament image shows no structures. Then set the stopper to the FILAMENT position.

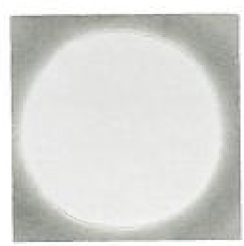
Obtain image at 50000× or higher, select a hole of about 5 mm dia. and overfocus the image slightly (using binoculars).



Fringe spacing around the hole is even

YES

NO

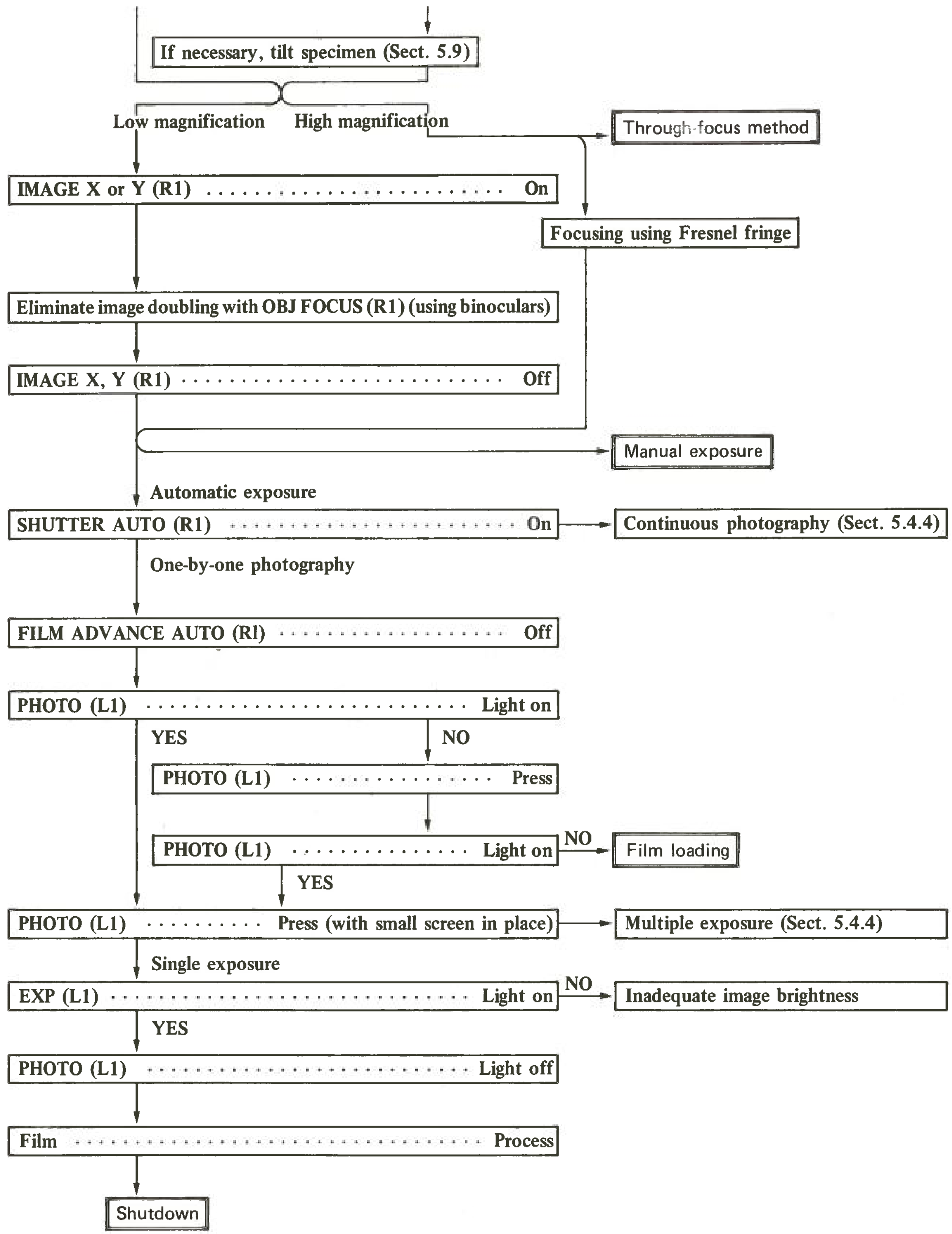


OBJ STIG1 (L1) · · · · · · · · · · · · · · · · · · On

Make spacing even with DEF (L1, R1)

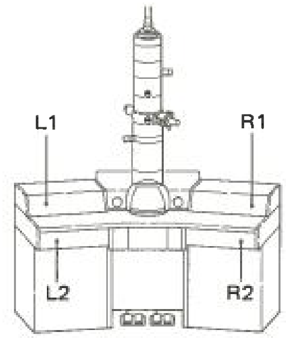
OBJ STIG1 (L1) · · · · · · · · · · · · · · · · · Off

Insert specimen and select field of view and magnification → Minimum exposure operation (MDS)



If necessary, tilt specimen (Sect. 5.9)
Low magnification
High magnification
Through-focus method
IMAGE X or Y (R1) .... On
Focusing using Fresnel fringe
Eliminate image doubling with OBJ FOCUS (R1) (using binoculars)
IMAGE X, Y (R1) .... Off
Manual exposure
Automatic exposure
SHUTTER AUTO (R1) .... On
Continuous photography (Sect. 5.4.4)
One-by-one photography
FILM ADVANCE AUTO (RI) .... Off
PHOTO (L1) .... Light on
YES
NO
PHOTO (L1) .... Press
PHOTO (L1) .... Light on
NO
Film loading
YES
PHOTO (L1) .... Press (with small screen in place)
Multiple exposure (Sect. 5.4.4)
Single exposure
EXP (L1) .... Light on
NO
Inadequate image brightness
YES
PHOTO (L1) .... Light off
Film .... Process
Shutdown

Finding electron beam



Routine operation

↓

BEAM CURRENT (L1) reading does not increase when FILAMENT (L1) is turned

↓

V3 (PAGE-3) · Open

- YES → continue below
- NO → Evacuate camera chamber and wait until V3 opens (then return to V3 check)

↓

BIAS MODE · 70 – 80

↓

FILAMENT (L1) · · · · · · · · · · · · · · · OFF → Stopper position

↓

BEAM CURRENT (L1) · · · · · · · · · · · · · · Reading increases

- YES → continue below
- NO → Electron gun filament replacement (Chap. 6)

↓

Illumination appears on screen when BRIGHTNESS (L1) is turned

- YES → Routine operation
- NO ↓

All lenses except PROJ (L2) · On

SHIFT (L1, R1) · Midpoint

↓

Illumination appears on screen when BRIGHTNESS (L1) is turned

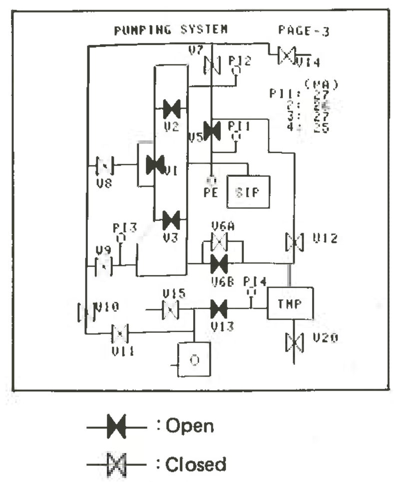
- YES ↓
- NO →

GUN ALIGN: SHIFT (R2) · · · · · · · · · · · · · · · · · · Midpoint

GUN ALIGN: TILT (R2) · · · · · · · · · · · · · · · · · · · Midpoint

GUN SCAN (L2) · On

↓



Find electron beam by adjusting BRIGHTNESS (L1)

GUN ALIGN: SHIFT: Y (R2)
GUN ALIGN: TILT: Y (R2)
BRIGHTNESS (L1)
} Adjust for maximum brightness

GUN SCAN (L2) . . . . Off

SHIFT (L1, R1)
BRIGHTNESS (L1)
} Adjust for maximum brightness; when illumination starts to glare, turn on PROJ (L2)

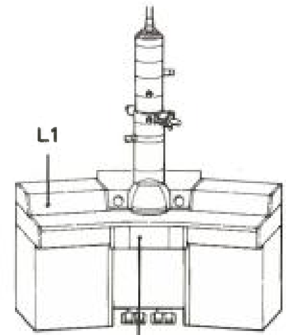
GUN ALIGN: SHIFT: X (R2)
GUN ALIGN: TILT: X (R2)
BRIGHTNESS (L1)
} Adjust for maximum brightness; when illumination starts to glare, turn on PROJ (L2)

Focus illumination on screen center with BRIGHTNESS (L1) and SHIFT (L1, R1)

Routine operation

Film loading

(Sect. 5.2.2)



FILAMENT (L1)	OFF
PHOTO (L1)	Check light off

↓

Camera chamber handle ······ Turn CW

↓ Wait about 15 min.

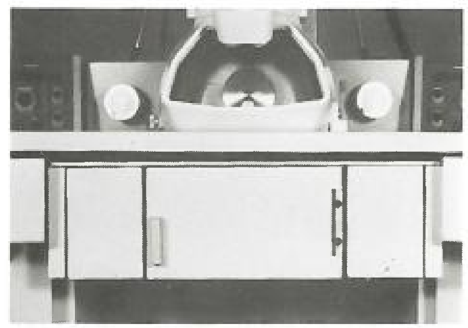
Camera chamber door ······ Opens

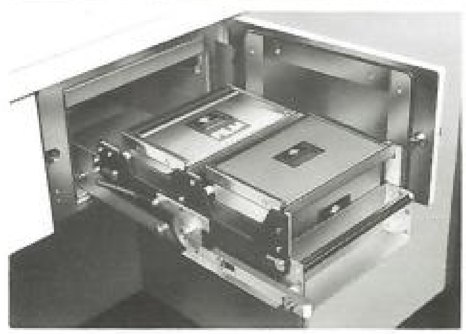
↓

Magazine stand ······ Draw out

↓

Magazine (film) ······ Change





Receiving magazine

Dispensing magazine

↓

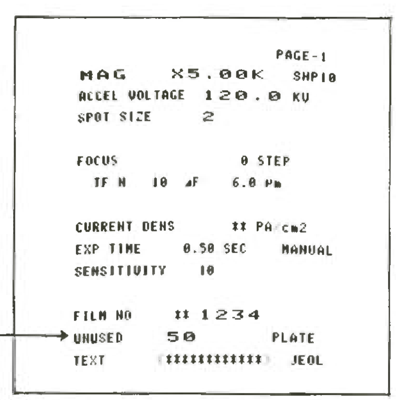
Camera chamber door ······ Close

↓

Camera chamber handle ······ Turn CCW

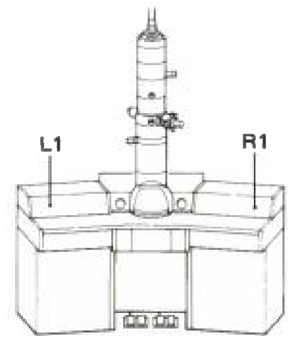
↓

UNUSED (PAGE 1) ····· Enter number of unused film sheets



Manual exposure

(Sect. 5.4.4)



Routine operation

↓

SHUTTER AUTO (R1) .... Off → Continuous photography (Sect. 5.4.4)

↓ One-by-one photography

FILM ADVANCE AUTO (R1) .... Off

↓

EXP TIME (R1) .... Enter required exposure time →

```
                              PAGE-1
MAG        X5.00K       SHP10
ACCEL VOLTAGE  120.0 kV
SPOT SIZE       2

FOCUS                   0 STEP
  TF N   10  ΔF    6.0 μm

CURRENT DENS          ** PA cm2
→ EXP TIME      0.50 SEC     MANUAL
SENSITIVITY     10

FILM NO      ** 1234
UNUSED       50            PLATE
TEXT         ************   JEOL
```

↓

PHOTO (L1) .... Light on

- YES → PHOTO (L1) .... Press
- NO ↓
  - PHOTO (L1) .... Press
  - ↓
  - PHOTO (L1) .... Light on
    - NO → No film (Change magazine)
    - YES ↓

PHOTO (L1) .... Press → Multiple exposure (Sect. 5.4.4)

↓ Single exposure

EXP (L1) .... Light on

- NO → Inadequate exposure time
- YES ↓

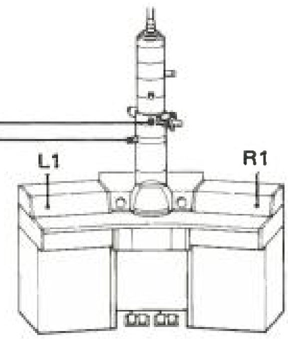
PHOTO (L1) .... Light off

↓

Film .... Process

Low magnification images

(Sect. 5.6.1)



Routine operation

↓

Objective aperture	Remove
Field limiting aperture	Remove
LOW MAG (R1)	Press

↓

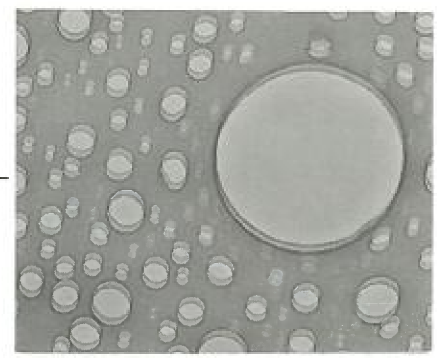
Voltage center	Align

↓

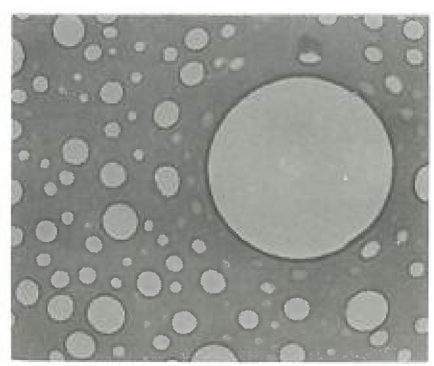
IMAGE X (R1)	On
OBJ STIG1 (L1)	On

↓

OBJ FOCUS (R1)	Eliminate image doubling



↓



↓

IMAGE X (R1)	Off
IMAGE Y (R1)	On

↓

Image	Doubling

NO → go to OBJ STIG1 (L1) / IMAGE Y (R1) Off

YES:

DEF (R1)	Eliminate image doubling

↓

IMAGE Y (R1)	Off
IMAGE X (R1)	On

↓

DEF (L1)	Eliminate image doubling

(return to IMAGE X (R1) Off / IMAGE Y (R1) On)

↓

OBJ STIG1 (L1)	Off
IMAGE Y (R1)	Off

↓

To increase image contrast, insert field limiting aperture

Dark field images

(Sect. 5.6.2)

Routine operation

↓

MAG1 (R1) ········ Press

↓

Select magnification and field of view

↓

Objective aperture ········ Remove
DIFF (R1) ········ Press

↓

BRIGHTNESS (L1) ········ Spread illumination

↓

SELECTOR (R1) ········ Camera length 40 – 120cm

↓

DIFF FOCUS (R1) ········ Focus diffraction pattern

↓

PROJ ALIGN (R2) ········ Center direct spot on screen

↓

DARK TILT (L1) ········ On

↓

DEF (L1, R1) ··· Center diffraction spot of interest on screen

↓

Objective aperture ········ Center on screen

↓

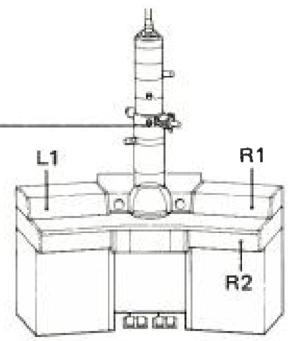
MAG1 (R1) ········ On

↓

BRIGHT TILT (L1) ········ On

↓ Dark field images ↑ Bright field images

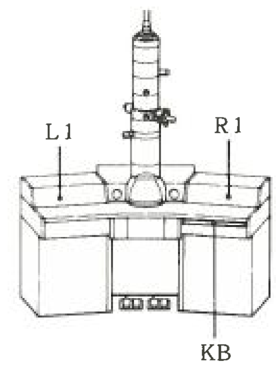
DARK TILT (L1) ········ On




```
                        PAGE-1
DIFF   120.0cm   SHP10
ACCEL VOLTAGE  120.0 KV
SPOT SIZE      2

FOCUS                 0 STEP
  TF H   10  ΔF

CURRENT DENS       ** PA/cm2
EXP TIME     0.25 SEC    MANUAL
SENSITIVITY    10

FILM NO     ** 1234
UNUSED     50          PLATE
TEXT       *************   JEOL
```

Through-focus method

(Sect. 5.6.3)



Routine operation

↓

OBJ 16× (R1) .... off

→ Automatic exposure:

SHUTTER AUTO (R1) .... on

→ Manual exposure:

SHUTTER AUTO (R1) .... off

EXP TIMER (R1) .... Set exp. time

↓

THRU FOCUS (KB) .... Press

U,O or space key (KB) .... Press

Enter number of exposures (50 or less) and focus step (1 – 9) per film

RETURN (KB) .... Press

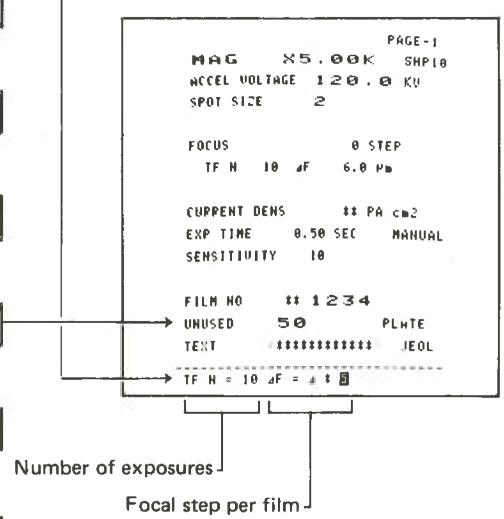
THRU FOCUS (KB) .... Press

Image .... Slightly overfocus

Unexposed films .... More than required

Receiving magazine .... Check for sufficient space

PHOTO (L1) .... Press



Minimum exposure operation (MDS)

(Sect. 5.6.4)

Routine operation

↓

PAGE (KB) .... Display PAGE-1

↓

Brightness and exposure time .... Set

↓

M D S RETURN RETURN (KB) .... Press

↓

IMAGE SHIFT (L1) .... On

↓

Image .... Reduce brightness

↓

Specimen shifting knobs .... Select field of view

↓

RETURN (KB) .... Press

↓

Magnification .... Set

↓

DEF (L1, R1) ..... Move field of view to outside of screen

↓

Image .... Focus

↓

RETURN (KB) .... Press

↓

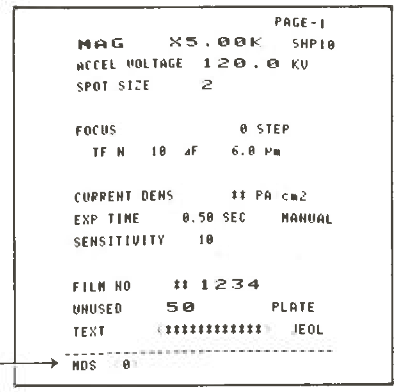
SHIFT (L1, R1) ..... Move illumination to outside of screen

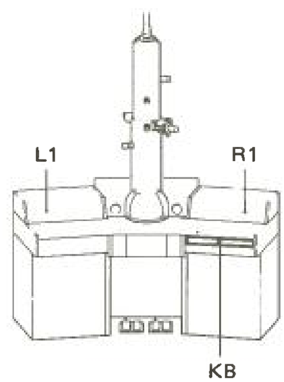
↓

PHOTO (L1) .... Press

To complete: M D S RETURN (KB) ..... Depress

To repeat: RETURN (KB) .... Press (return to Image ... Reduce brightness)





Selected area electron diffraction

(Sect. 5.7.1)

Routine operation

↓

DIFF (R1) ································ Press

↓

SELECTOR (R1) ················ Camera length 250 cm

↓

DIFF FOCUS (R1) ················ Focus direct spot

↓

PROJ ALIGN (R2) ·········· Center direct spot on screen

↓

Field limiting aperture ······················ Insert

↓

SAM ROCK (R1) ························· Press

↓

Select field of view and magnification and roughly focus image

↓

If necessary, record selected area image

↓

Objective aperture ······················· Remove

↓

DIFF (R1) ································ Press

↓

SELECTOR (R1) ······ Select camera length (10 – 250cm)

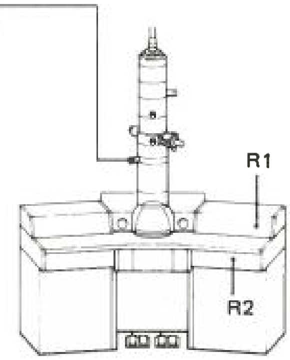
↓

DIFF FOCUS (R1) ············ Focus diffraction pattern

↓

Record pattern (Manual exposure)

```
                              PAGE-1
DIFF     250.0cm     SHP10
ACCEL VOLTAGE   120.0 KV
SPOT SIZE        2

FOCUS                  0 STEP
  TF N    10   ΔF

CURRENT DENS        ** PA cm2
EXP TIME      0.25 SEC     MANUAL
SENSITIVITY     10

FILM NO       ** 1234
UNUSED       50           PLATE
TEXT        <************    JEOL
```



Microbeam electron diffraction

(Sect. 5.7.2)

Routine operation

↓

Camera length .... 250 cm

↓

DIFF FOCUS (R1) .... Focus direct spot

↓

PROJ ALIGN (R2) .... Center direct spot on screen

↓

Select magnification in range of 4,000 to 500,000×, move the field of view of interest to screen center and focus image

↓

Expose the entire field of view (1st exposure in double exposure)

↓

Condenser aperture .... Largest

Objective aperture .... Remove

SPOT SIZE (L1) .... Minimum

↓

BRIGHTNESS (L1) .... Focus illumination

SHIFT (L1, R1) .... Center illumination on screen

↓

Expose the field of view of interest for diffraction (2nd exposure in double exposure)

↓

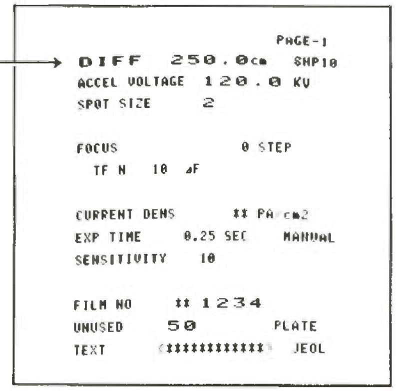
Camera length .... 10 cm

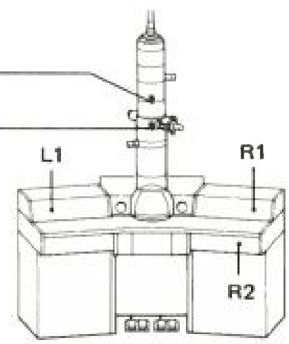
↓

DIFF FOCUS (R1) .... Focus diffraction pattern

↓

Record diffraction pattern (manual exposure)





High dispersion electron diffraction

(Sect. 5.7.3)

Routine operation

↓

Select magnification and field of view and record

↓

LOW MAG (R1) ························· Press

↓

Magnification ························· ~ 500×

↓

Field of view for diffraction ············· Center on screen

↓

Select smallest objective aperture and center it on screen

↓

If necessary, record the field for diffraction

↓

Camera length ····················· 400 cm or longer

↓

Direct spot ··························· on screen

- YES → DIFF FOCUS (R1)
- NO ↓

BRIGHTNESS (L1) ·········· Turn CCW

↓

SHIFT (L1, R1) ·· Center direct spot on screen

↓

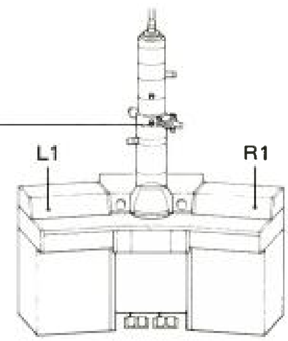
DIFF (R1) ···················· Press

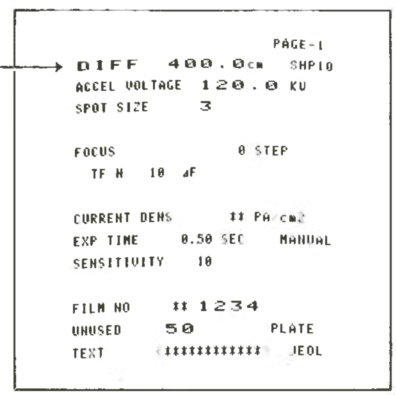
↓

DIFF FOCUS (R1) ················· Focus direct spot

↓

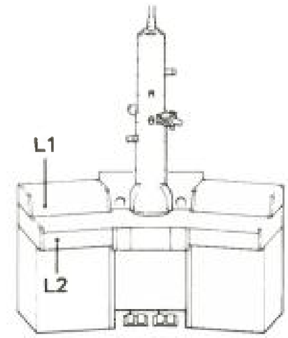
Record diffraction pattern by manual exposure





Electron gun filament replacement

(Sect. 6.1)



FILAMENT (L1)	OFF
HT (L1)	Off
GUN AIR (L2)	On

↓ Wait until the PIG2 indicates 250μA.

LIFT (L2) ······ On

↓

Anode chamber ······ Cover

↓ Wait for Wehnelt to cool

Electron gun ······ Check grounding

↓

Cylinder ······ Remove

↓

Wehnelt ······ Disassemble

↓

Wehnelt ······ Clean (Sect. 6.7)

↓

Filament ······ Replace
Wehnelt ······ Assemble

↓

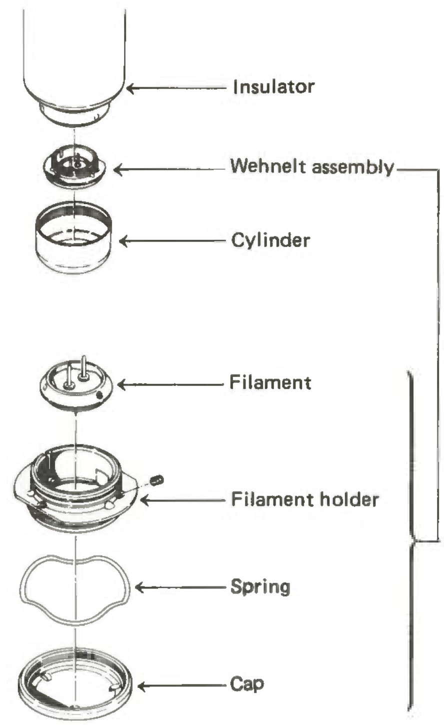
Wehnelt cap ······ Adjust (1.0 mm)

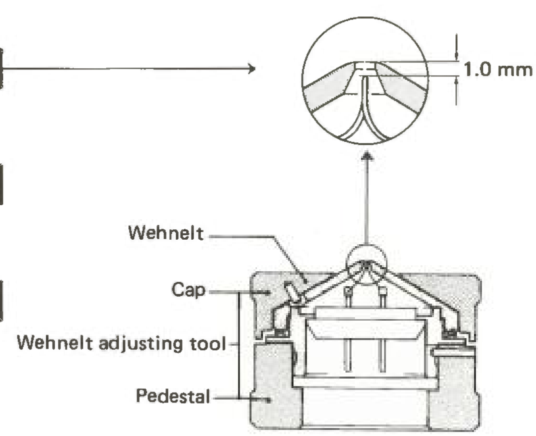
↓

Wehnelt, cylinder ······ Replace

↓

GUN AIR (L2) ······ Off





Baking out the column

(Sect. 6.9)

Accelerating voltage reading ···················· 120kV

↓

FILAMENT (L1) ······························ Off

HT (L1) ··································· Off

↓

LENS POWER SUPPLY (L2) ······················ On

↓

BAKE OUT (L2) ······························ On

↓

Lens cooling water manual valve ·················· Close

↓ Leave for 10 hours

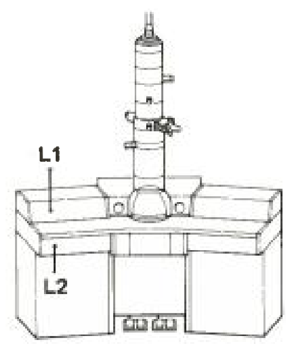
LENS POWER SUPPLY (L2) ······················ Off

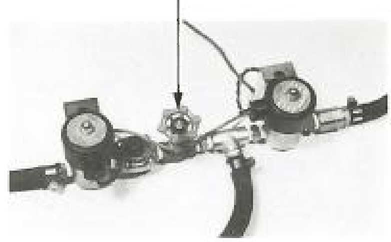
BAKE OUT (L2) ······························ Off

↓ Leave for 1 hour

Lens cooling water manual valve ··············· Open fully

LENS POWER SUPPLY (L2) ······················ On





Procedure for software reset.

Only to be done by experienced users after things have gone badly wrong and hard reset fails

1. type CTRL-A — check for asterisk top left. If not repeat
2. type reset — Keep checking for asterisk if gone type CTRL-A again
3. type ext=off — " "
4. type pp = off — " "
5. type CTRL-A — to remove asterisk

You will then need to set

film no., unused films

ATTACHMENTS

The operating instructions for the main attachments are enclosed even though those attachments may not form part of your instrument system.

INSTRUCTIONS

EM-ACD10

ANTI-CONTAMINATION DEVICE

No. IEM1200EX-ACD10
(EM553001)

1. GENERAL

Use of the EM-ACD10 reduces specimen contamination caused by electron beam irradiation. Therefore, this device is useful in that valuable specimens can be preserved after the completion of microscopy. Also, specimens can be observed at high resolving power and at high magnification.

2. SPECIFICATIONS

Refrigerant tank capacity: 300 cc

Refrigerant preservation time: 7 hours

Grounding check circuit and over-heat-prevention device are included.

3. COMPOSITION

Refrigerant tank

Refrigerant drainer (with heater)

Funnel

4. INSTALLATION (See Figs. 1 and 2)

1. Remove the specimen holder.
2. Admit air into the column.
3. Remove covers A and B.
4. Install the refrigerant tank to where cover A was, and connect the braided wire to the cooling rod.
5. Replace covers A and B, and evacuate the column.
6. Connect the ACS cable, protruding from the console, to the refrigerant tank.

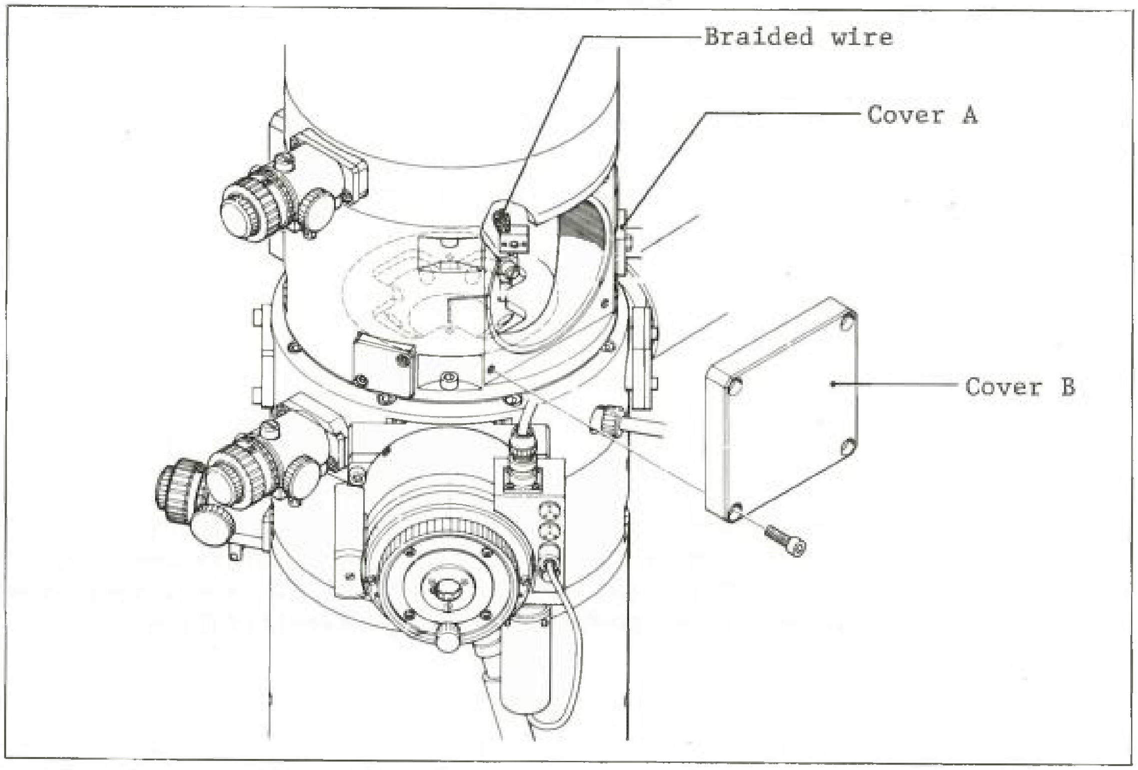

Braided wire
Cover A
Cover B

Fig. 1

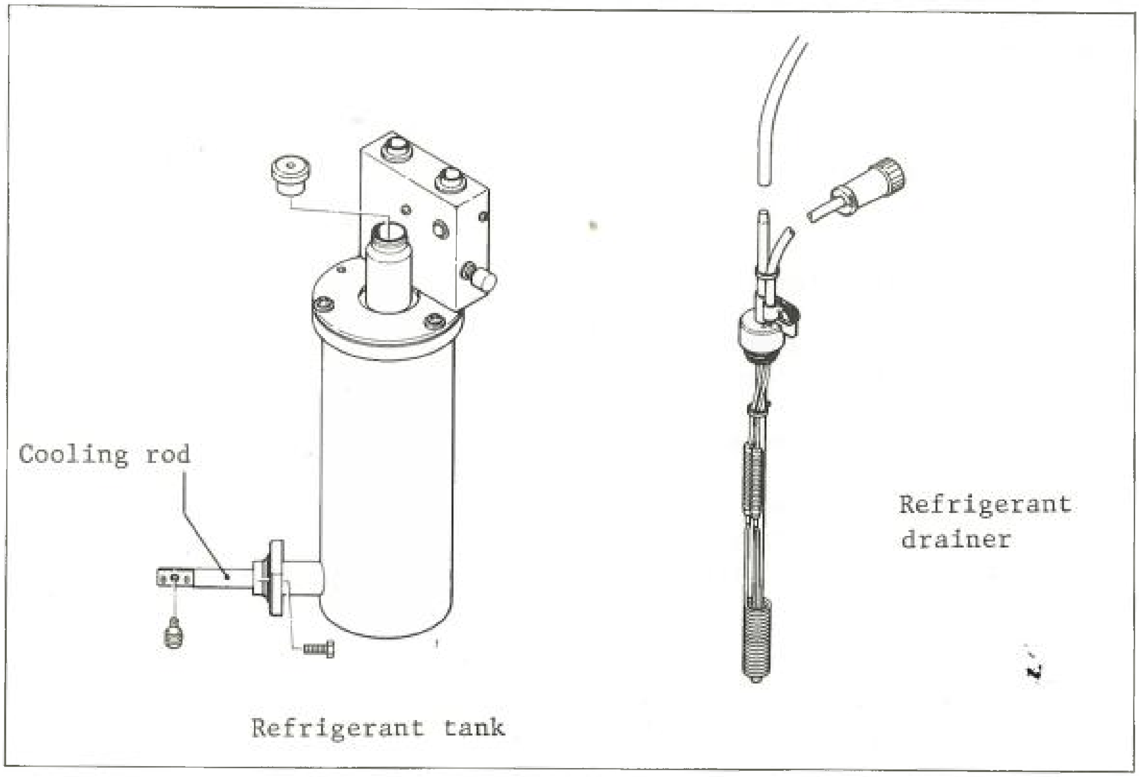

Cooling rod
Refrigerant drainer
Refrigerant tank

Fig. 2

5. HOW TO USE

5.1 Filling the refrigerant tank

1. Make sure that the reading of the PENNING GAUGE (1200EX control panel L2-10) is less than 0.1 Pa (10^{-3} Torr).
   Caution: If the refrigerant tank is cooled with liquid nitrogen when the gauge reading is more than 0.1 Pa (that is, when the column pressure is not sufficiently low), the residual moisture in the column air will condense into water and envelop the trap. This will cause oxidation of the trap and charging with electrons, resulting in an increase of objective lens astigmatism and fluctuation of the electron beam.
2. Insert the funnel into the tank.
3. Fill the tank with liquid nitrogen and wait for 15 minutes.
4. Replenish the tank once again.
5. Remove the funnel from the refrigerant tank and insert the cap into the opening.
   Caution: Do not admit air into the column unless the trap temperature has risen to room temperature (see Subsect. 5.2).

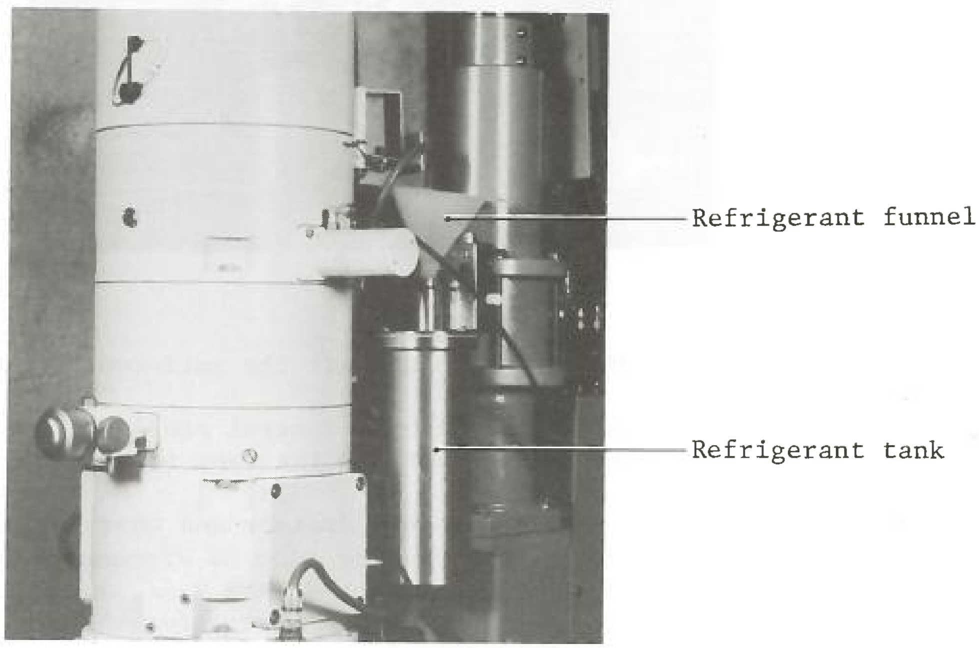


Fig. 3

5.2 Raising the trap temperature to room temperature

If air is admitted into the column when the trap is cooled down, moisture in the air will condense and ice will form, the latter enveloping the trap. It is, therefore, necessary to raise the trap temperature to room temperature before admitting air into the column.

1. Protect the viewing window glass with the cover that is provided.
2. Insert the refrigerant drainer into the tank (Figs. 2 and 4).

   Caution: Since the liquid nitrogen remaining in the tank passes through the drain tube at a fairly brisk rate and may splash on the operator or viewing window, a suitable plastic container should be kept ready. Insert the free end of the drain tube into the container before inserting the drainer into the tank.

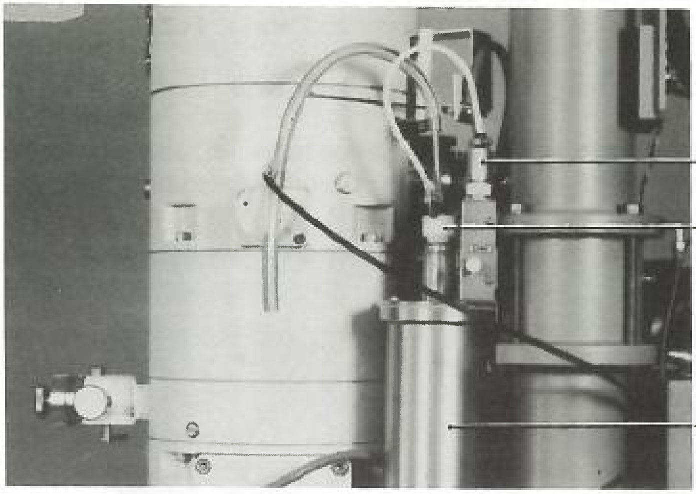


Fig. 4

3. Plug the refrigerant drainer plug into the anti-contamination device HTR socket.
4. Depress the ACD HEAT button (1200EX control panel L2-6). The built-in button lamp now lights up. Wait for the lamp to go out (takes approx. 15 min).
5. When the lamp goes out, remove the drainer and wait for another 15 min.

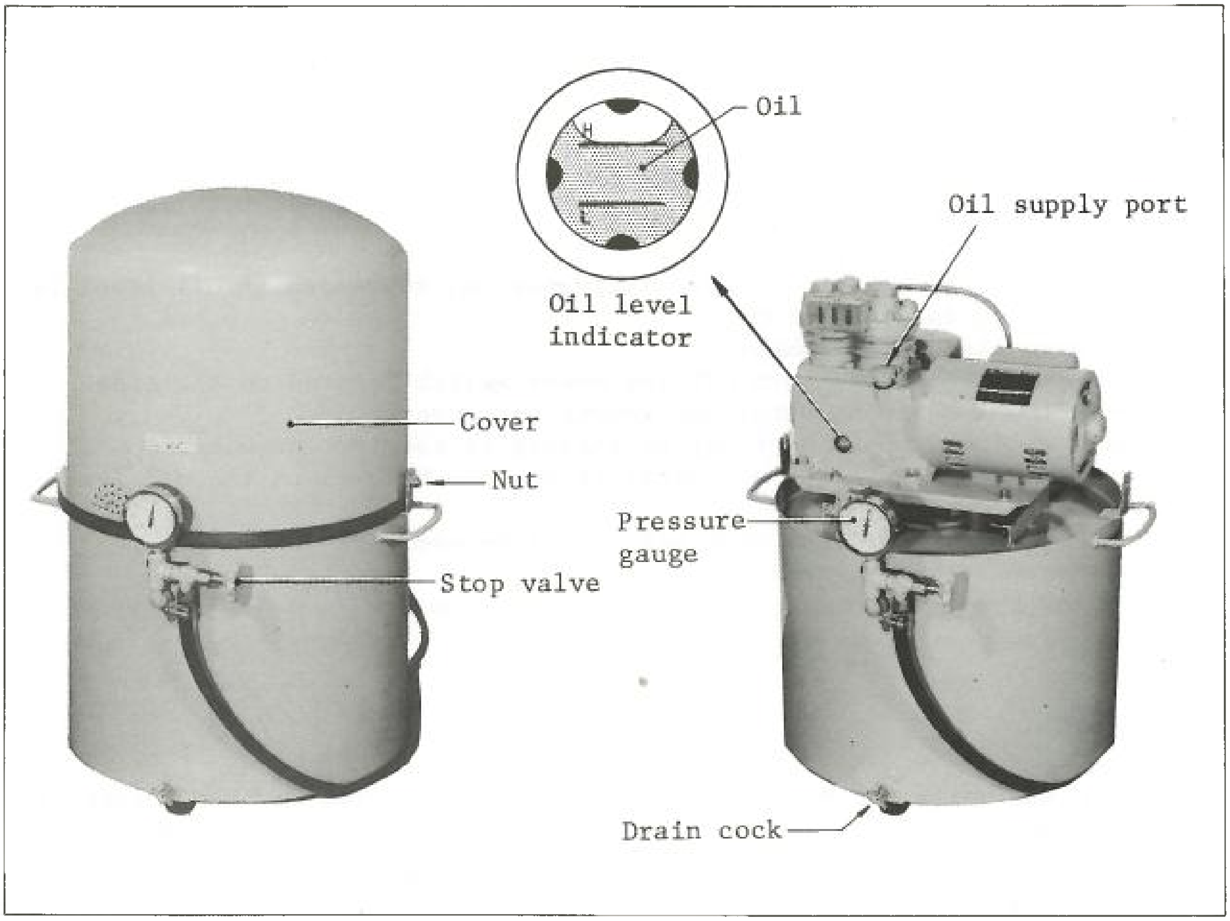
   Notes: 1. If the refrigerant drainer plug is disconnected while the ACD HEAT button lamp is lit, the lamp will remain lit. In this case, re-insert the plug, and wait for the lamp to go out.

   2. In order to terminate trap heating before the trap reaches room temperature, depress the ACD HEAT button, and keep it depressed (for several seconds) until the button lamp goes out.

INSTRUCTIONS

EM-CP10
COMPRESSOR

No. IEM1200EX-CP10
(EM564001)



1. GEMERAL

The EM-CP10 Compressor supplies compressed air to the pheumatic valves used in the EM evacuation syrtem.

2. SPECIFICATIONS

. Power supply:	Single phase 100 V, 1 kVA, 50/60 Hz
. Available air pressure:	$3.5 \sim 4.7 \times 10^5$ Pa
. Dimensions:	460 mmϕ × 710mm(H)
. Weight:	40 kg

3. INSTALLATION

1. Connect the cable to the power supply (which should be 100 V, 1 kVA or more).
2. Connect the EM compressed air hose to that of the compressor.
3. Turn on the power switch located on the side of the compressor.
4. Open the stop valve.

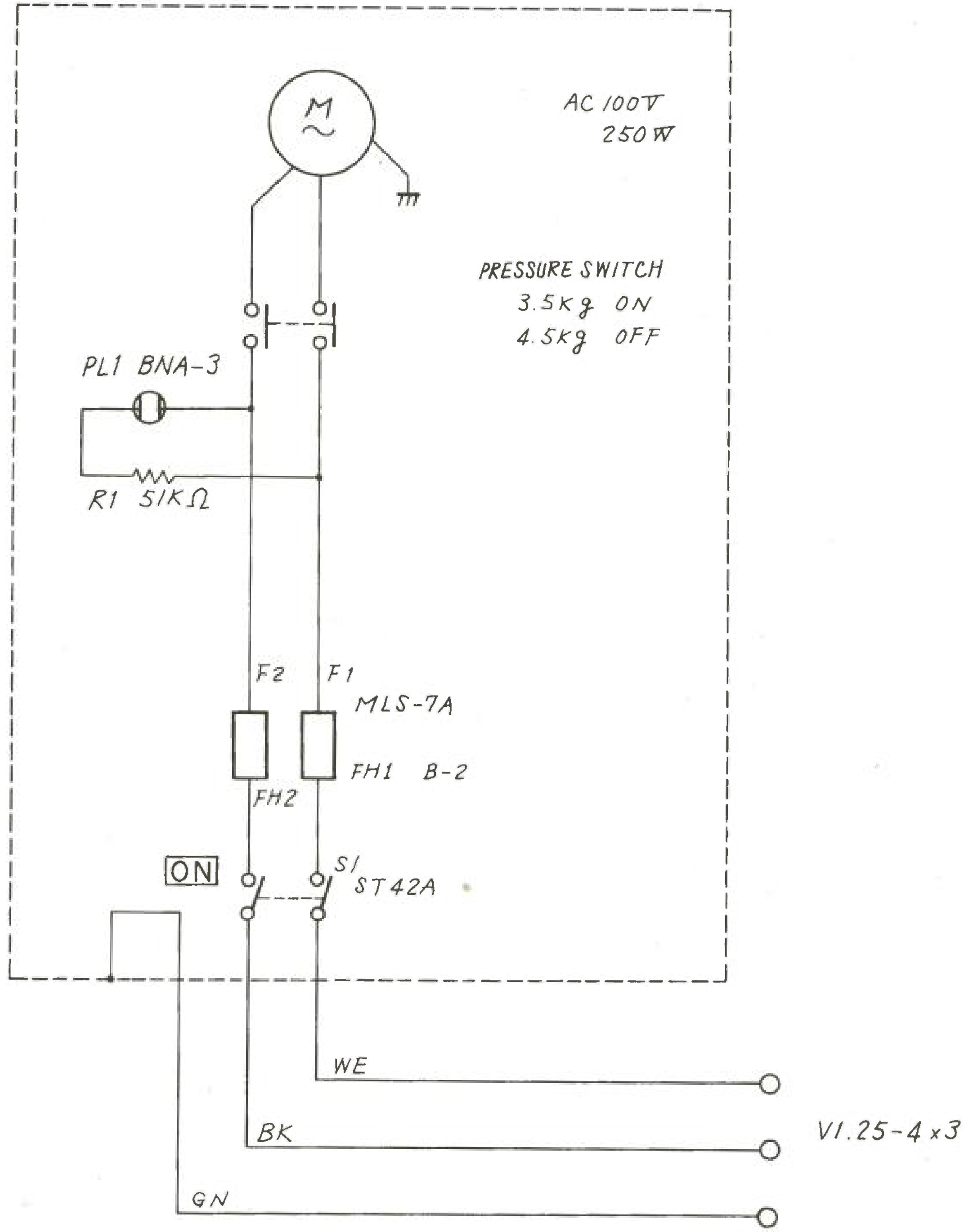
4. OIL REPLENISHMENT

Check the compressor oil level indicator and replenish if oil level is below L-level on the indicator.

1. Shut down the EM instrument.
2. Close the stop valve; turn off the power switch located on the side.
3. Loosen the two fixing nuts, and remove the cover.
4. Remove the oil supply port cap by turning it counterclockwise.
5. Feed provided compressor oil until it reaches H-level on the oil level indicator.
   Note: Be careful oil fed does not exceed H-level.
6. Replace the cap and cover.
7. Turn the power switch on, and open the stop valve.

5. DRAINAGE

Drain the water two or three times a year by opening the drain cock ofter shutting down the EM and the compressor. Be sure to close the drain cock after completing drainage.



COMPRESSOR	606112839

INSTRUCTIONS

EM-DCS10

DP CASCADE SYSTEM

No. IEM1200EX-DCS10
(EM555001)

1. GENERAL

The EM-DCS10 is a cascade-connected evacuation system using two special made oil diffusion pumps (DP1 and DP2) in place of a sputter-ion pump and turbomolecular pump. The lower oil diffusion pump DP2 evacuates the microscope viewing and camera chambers, and also evacuates the upper oil diffusion pump DP1 which evacuates the specimen and anode chambers. In this method, since the back pressure of the DP1 is maintained at a high vacuum of 10^{-3} Pa by means of the DP2, the self-cleaning ability of the DP1 is increased thus preventing oil in the DP1 from oxidizing and enabling ideal DP1 functioning.

2. SPECIFICATIONS

◦ Obtainable lowest pressure:	10^{-5} Pa order.
◦ Evacuation control:	Fully automated.
◦ Vacuum valves:	Pneumatic and solenoid types.

3. COMPOSITION

- ◦ 4-inch oil diffusion pump .... 2 sets
- ◦ Water-cooled baffle .... 2 sets
- ◦ Induction preventing coil .... 1 set
- ◦ Pirani gauge .... 4 sets
- ◦ Penning gauge .... 1 set
- ◦ Evacuation pipes and others .... 1 set
- ◦ Control circuit .... 1 set

2

4. PRINCIPLE OPERATION

Fig. 4.1a shows the structure of a Gaede oil rotary pump currently being used with JEM electron microscopes. The interior of the pump contains oil, which serves to lubricate the pump and make it airtight. When the rotor turns in the direction of the arrow, the gas in one chamber is compressed so that the pressure is greater than the atmospheric pressure. As a result, the gas is pumped out through the exhaust valve into the atmosphere. Simultaneously, gas enters the other chamber ready for the next compression stage. That is to say, two pumping processes take place as the rotor rotates through one revolution. Moreover, since the pump used with the JEM is a two-stage type, vibration and exhaust noise levels are low. However, since the attainable pressure is only about 10^{-3} Torr at a pumping speed of several tens of liters/min, the vacuum required for electron microscopes cannot be obtained by this pump alone. It is, therefore, used for the initial (rough) pumping procedure and for maintaining the back pressure of the oil diffusion pump.

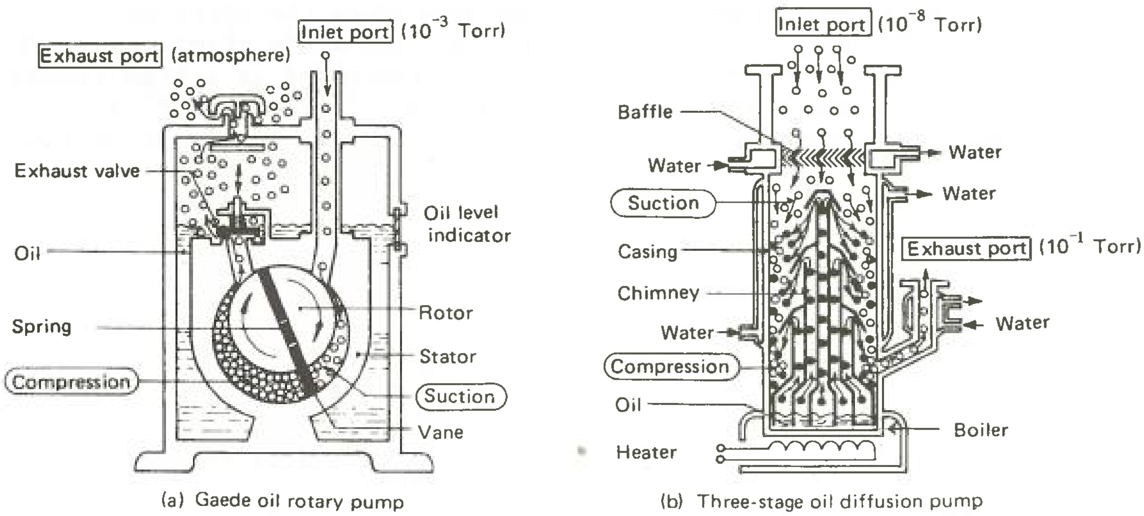


Fig. 4.1 Structure of vacuum pumps

Fig. 4.1b shows the structure of a three-stage oil diffusion pump equipped with a water-cooled baffle. The baffle serves to prevent any back-streaming of oil vapor. The oil diffusion pump itself is composed of a boiler containing a heater, a water-cooled casing, and a three-stage jet chimney. The oil heated by the boiler enters the chimney as vapor which is jetted through a nozzle into the low pressure section at a supersonic speed. By so doing, the gas molecules from the column diffuse into the oil jet stream and the intermingled gas compressed by the kinetic energy of the jet flow and transferred to the exhaust port. The jetted oil vapor is condensed

by the water-cooled casing and the condensed oil drains back into the boiler. The volatile component in the recovered oil is removed by evaporation (fractional distillation). Because the pressure on the suction side (suction pressure) must be low (10^{-1} Torr or less) in order to start the oil diffusion pump and the pressure on the exhaust side (back pressure) cannot be increased to that of the atmosphere (the back pressure is approx. 10^{-1} Torr), an oil rotary pump is used as an auxiliary pump. The minimum obtainable pressure possible with an oil diffusion pump is approx. 10^{-8} Torr (at a pumping speed of several hundred liters/sec), but this value can be improved on by using a trap.

The measuring method employed for low pressures (degree of vacuum), must be selected according to the degree of pressure, type of gas to be measured, etc. The range of values to be represented depends roughly on the measuring method. Ordinary electron microscope vacuum systems use high-precision hotcathode ionization vacuum gauges. However, these devices are unsuitable for automatically controlling the vacuum system of an electron microscope, since they cannot be used under atmospheric conditions. JEM electron microscopes employ a Pirani type gauge. Fig. 4.2 shows the circuit of a constant-voltage Pirani gauge. The Pirani and dummy tubes are encased under the same conditions. The port of the Pirani tube is connected to the column while the dummy tube is sealed to secure the vacuum. The electrical resistance R_1 of the Pirani tube is roughly equal to resistance R_2 of the dummy tube at room temperature, but when a constant-voltage power E is supplied, their resistances increase due to the resultant increase in temperature. The actual temperature of the respective resistors is determined by the heat conductivity of the residual gas which, in turn, depends on the pressure. At low pressure, when R_4 is roughly adjusted to R_3 so as to balance the bridge, an increase in pressure upsets the balance of the bridge and the ammeter M detects current i which is determined by the degree of imbalance (max. i is adjusted by R_5). This method permits the pressure to be directly read on the ammeter from atmospheric pressure to low pressure.

Fig. 4.3 shows a basic vacuum system, comprising an oil rotary pump (RP), an oil diffusion pump (DP), a vacuum gauge (VG) and five valves. The operating procedure is as follows when valves Va, Vb, Vc and Vd are closed and Ve is open.

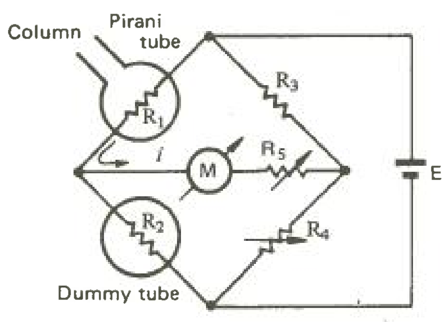


Fig. 4.2 Pirani gauge circuit

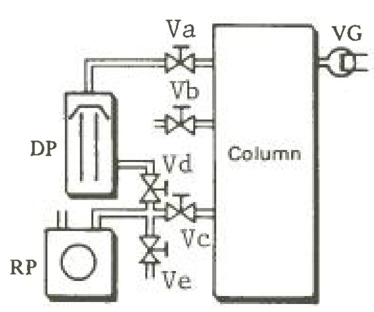


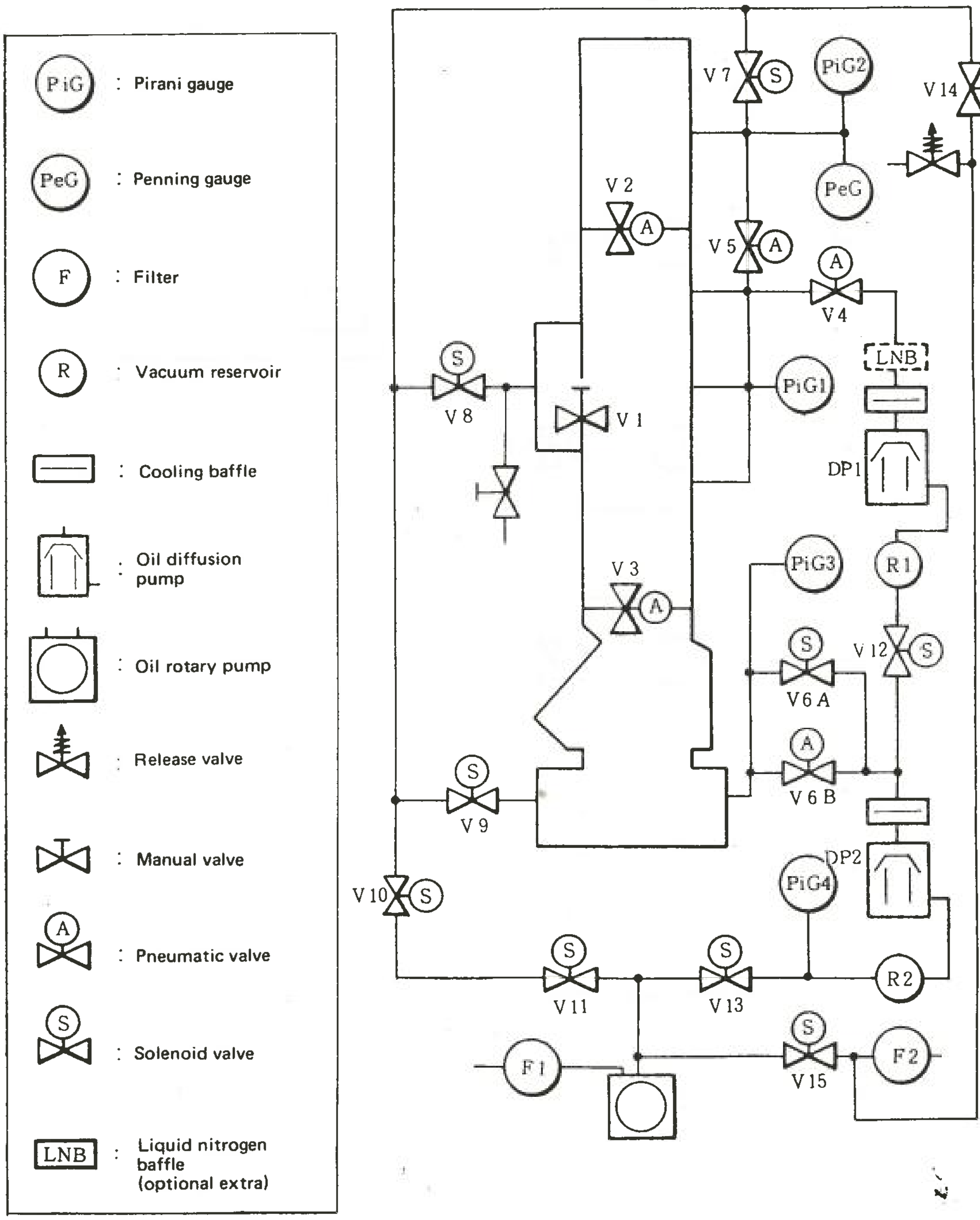
Fig. 4.3 Basic structure of the vacuum system

- Start-up: Close leak valve Ve and turn on the RP switch. Then open Vc, and turn on the heater to heat the DP.
- Evacuation: Close Vc and open Vd for rough pumping ($\sim 10^{-2}$ Torr). Then close Vd, and open Vc and Va (in that order) to achieve a vacuous state (10^{-5} Torr or less).
- Leaking and re-evacuation: Close Va and open Vb to admit air into the column. Then close Vb and re-evacuate.
- Shutdown: Close Va and turn off the heater to cool the DP. Then close Vc, turn off the RP switch and open Ve.

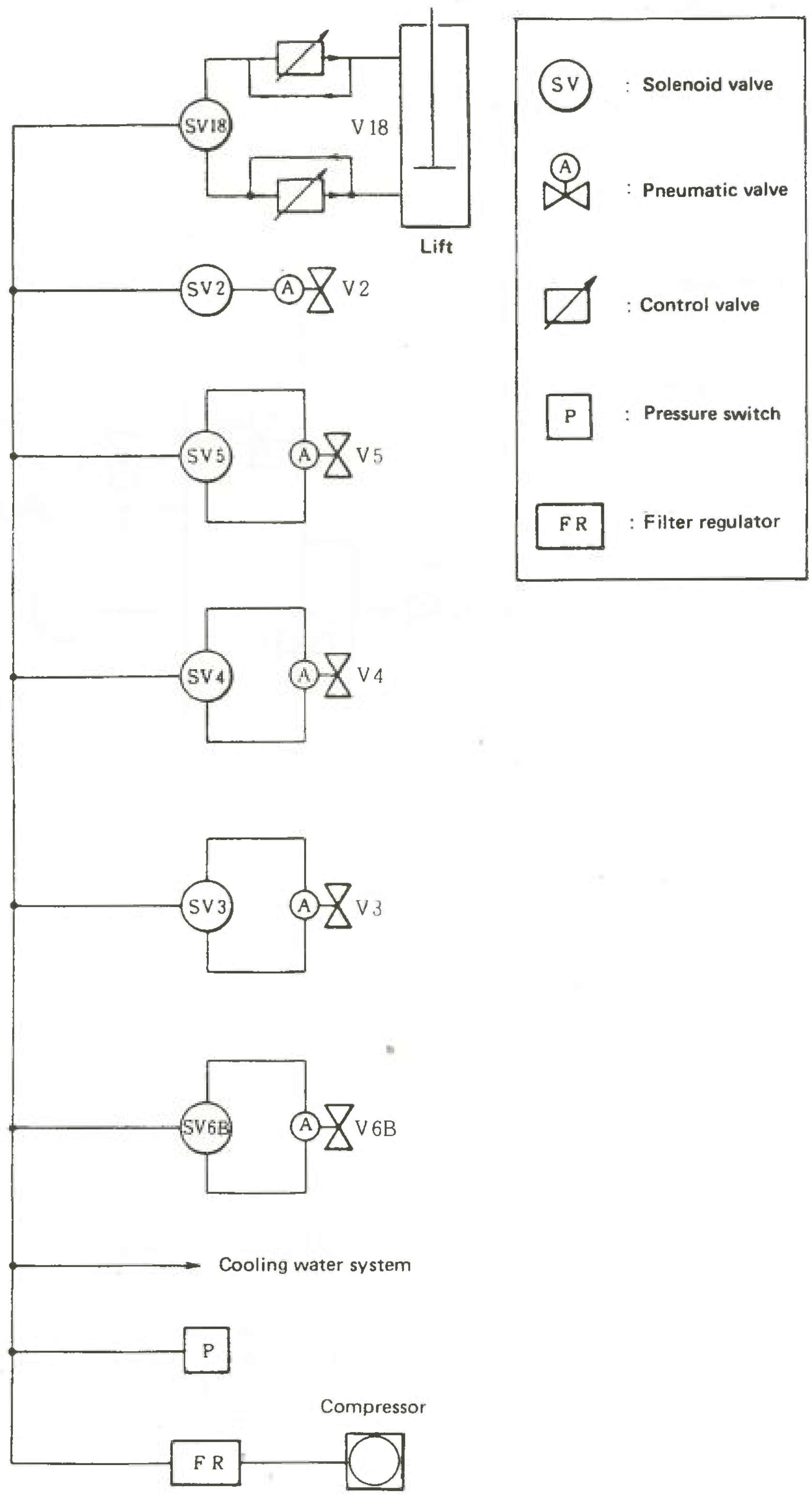
The vacuum system of the electron microscope consists of an oil rotary pump, two oil diffusion pumps, and many solenoid and pneumatic valves, which are automatically controlled by vacuum gauges (VG) and timers.

5. SYSTEM DIAGRAMS

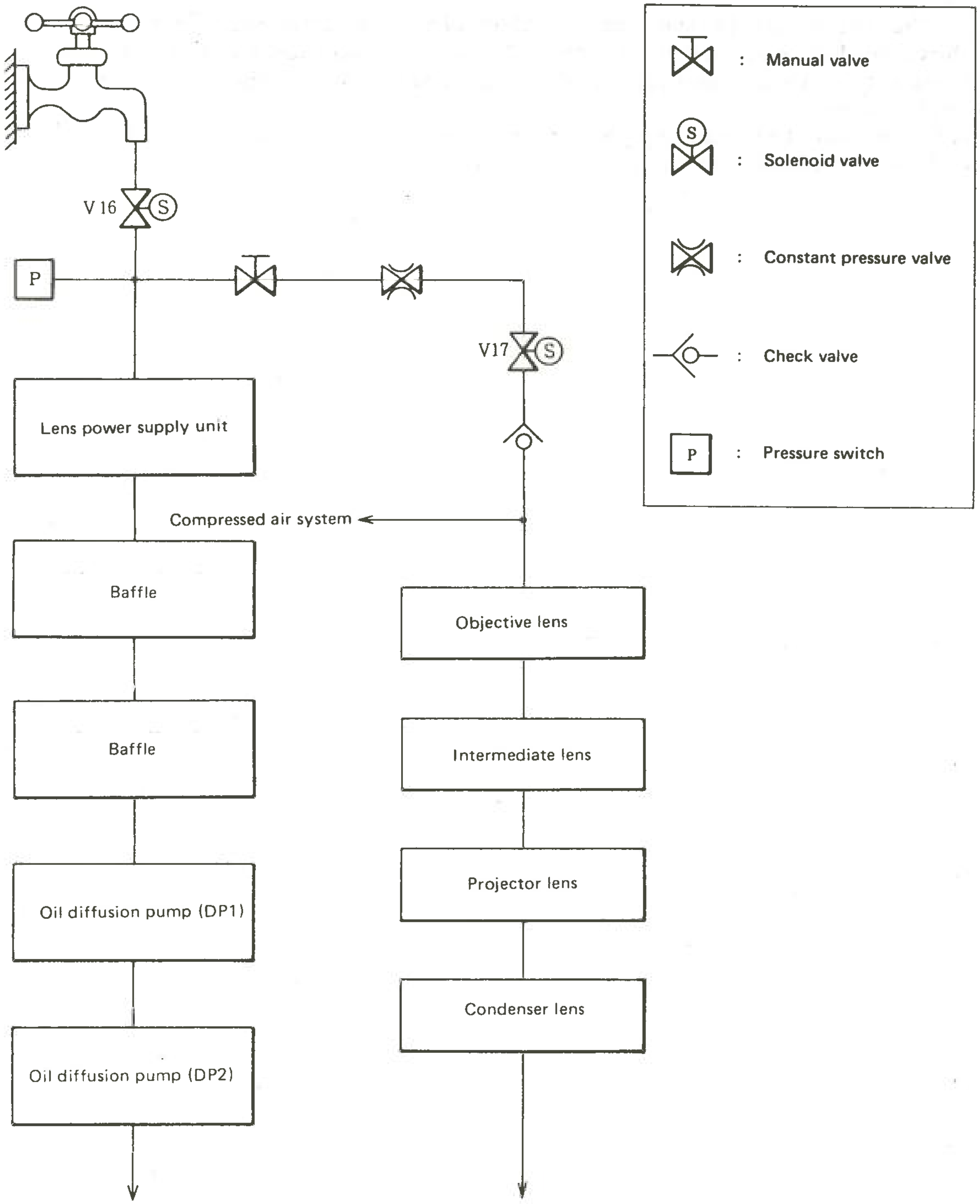
The vacuum system, compressed air system and cooling water system are illustrated in the following schematic and block diagrams.



Vacuum system



Comprresed air system



Cooling water system

6. OPERATION AND MAINTENANCE

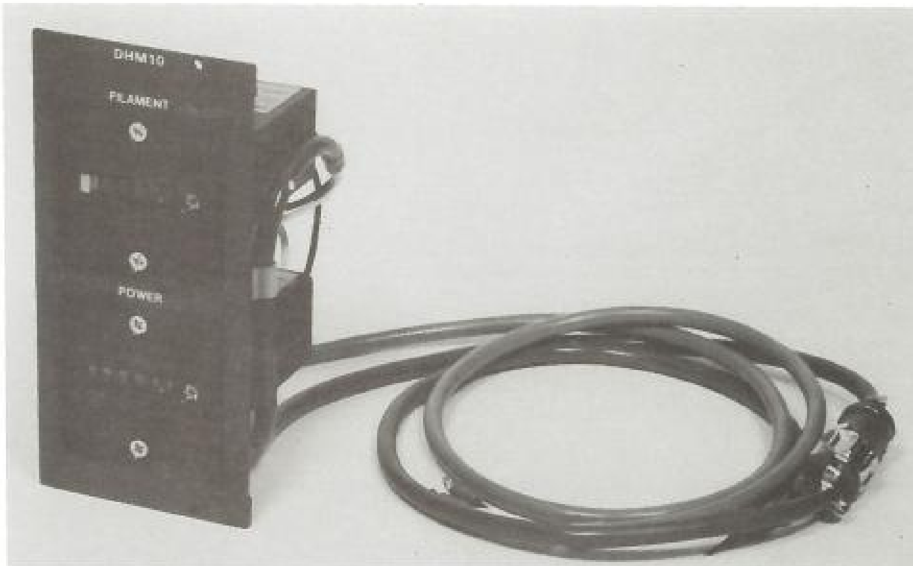
The operation is the same as that when a sputter-ion pump and turbomolecular pump are used (see JEM-1200EX Instruction manual). The instrument stops automatically when the heater(s) of the oil diffusion pumps break(s) down.
After long use the pumping performance drops due to oxidation of oil. In that case, replace the oil.

INSTRUCTIONS

EM-DHM10

DIGITAL HOUR METER

No. IEM1200EX-DHM10
(EM570001)



1. GENERAL

The EM-DHM10 Digital Hour Meter is used for adding up separately the number of hours the electron gun filament was ignited and the number of hours EM was operating.

2. SPECIFICATIONS

. Electron gun filament ignition hour meter:	Capable of adding up to 9999.9 hours. Equipped with reset button.
. EM operating hour meter:	Capable of adding up to 99999.9 hours.

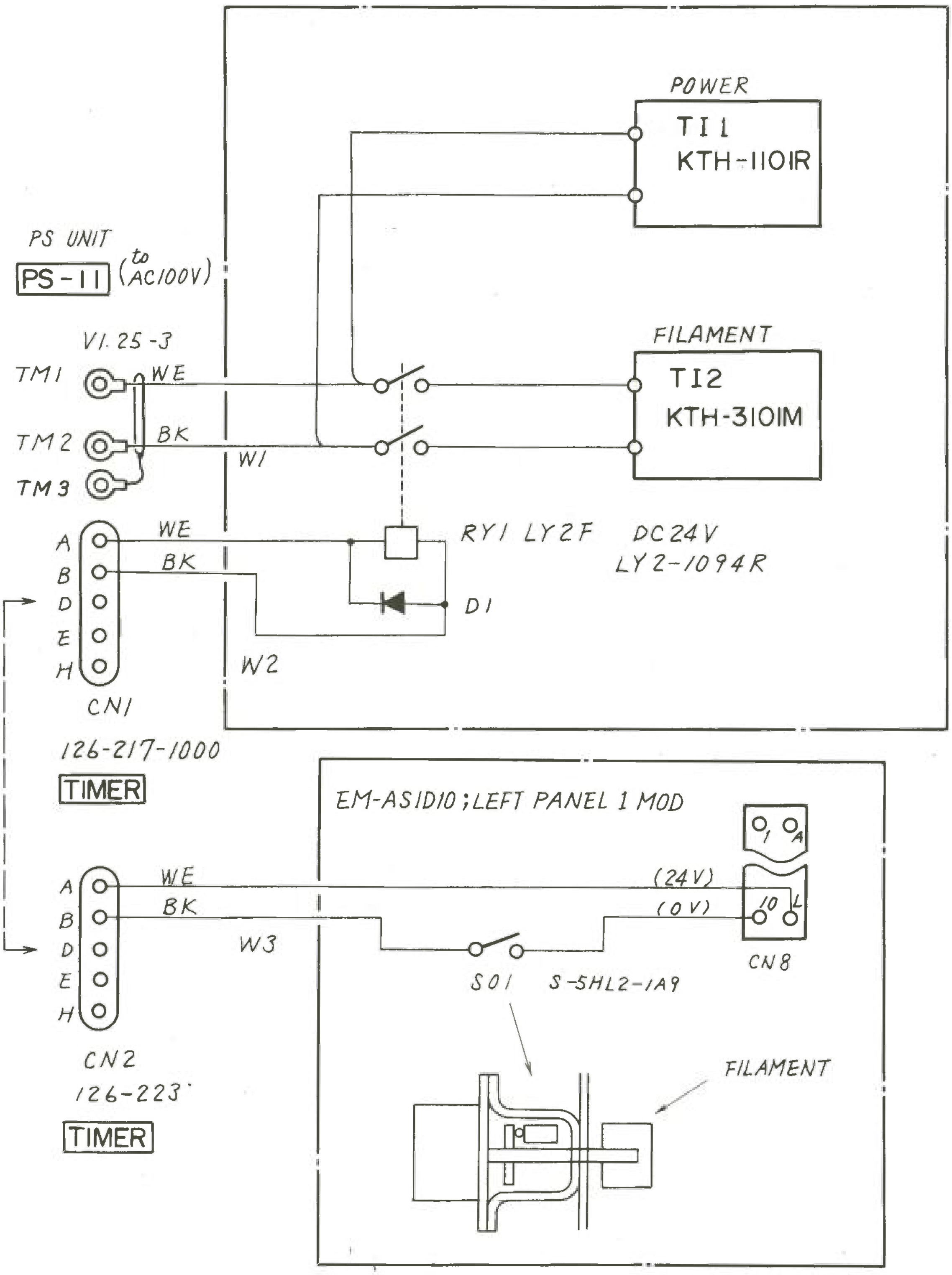
3. INSTALLATION

1. Set the EM-DHM10 in the left control panel.
2. Connect TIMER cable of the EM-DHM10 to connector TIMER located in the

left console, and the power supply cables of the EM-DHM10 to 5 and 6 of connector PS-11 located on the left console rear panel.

4. OPERATION

The EM operating hour meter starts operating when the EM control panel POWER switch is turned on. The electron gun filament ignition hour meter starts operating when the control panel FILAMENT knob is set to other than the fully-counterclockwise position.



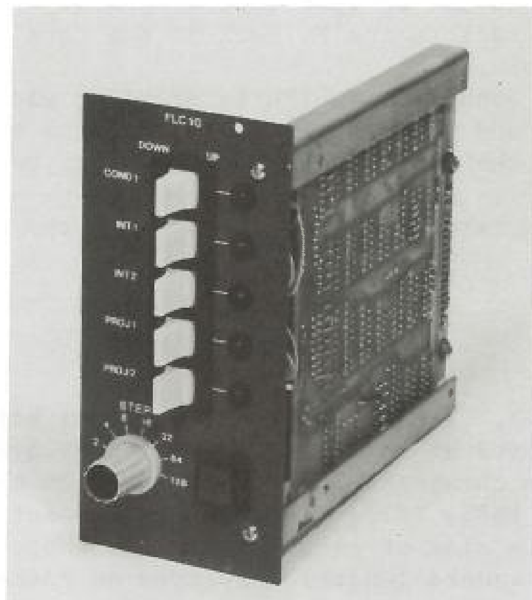
TIMER UNIT | 606112367

INSTRUCTIONS

EM-FLC10

FREE LENS CONTROL UNIT

No. IEM1200EX-FLC10
(EM568001)



1. GENERAL

When the EM-FLC10 Free Lens Control Unit is attached to the JEM-1200EX, each lens current of the microscope can be freely varied. If this unit is used in conjunction with the lens system memory key (USERS) located on the EM keyboard, current values of all the lenses which have been set by the EM-FLC10 can be instantly stored and set up again.

2. SPECIFICATIONS

. Controllable lenses:	CL1, IL1, IL2, IL3, PL
. Variable current range:	0 ∿ maximum value of each lens
. Maximum current:	5-stage relative correction, 40, 60, 80, 100, 120 kV
. Minimum changeable current:	8-steps switchover, 1/4095 ∿ 128/4095 of maximum current.

3. COMPOSITION

- Main unit
- Printboard
- Cable

4. INSTALLATION

1. Set the main unit in the EM left control panel.
2. Slide the printboard into the FC rack of the card rack located in the rear of the right console.
3. Connect the cable connector, which is provided with the shield terminal, to the printboard and the other connector to the main unit. The cables should be laid in the duct located in the upper portion of the center console.
4. Connect the shield terminal to the chassis of the card rack.

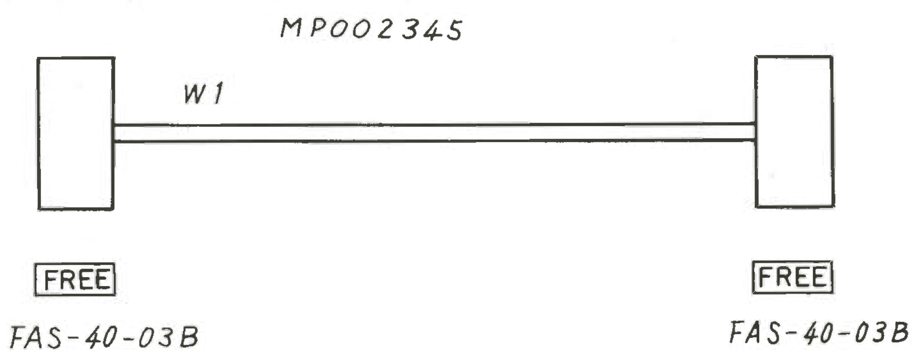
5. OPERATION

1. Turn FREE switch ON. The built-in lamp becomes bright, and "FREE LENS CONTROL" is displayed at the top of PAGE-1(displayed on EM CRT).
2. Select the minimum changeable current value with the STEP knob.
3. Use switch COND1, INT1, INT2, INT3 and PROJ to set the respective current. Lamp located by the side of each switch lights up. At the same time, the magnification (or camera length) displayed on PAGE-1 disappears.
   Note: CL2 current can be varied by means of the DIFF FOCUS knob (on the EM control panel) when EM-ASID10 is also used. CL2 current cannot be varied, however, if SAM/ROCK and DIFF switches on the EM right control panel are on.
4. To return to the normal lens system, turn off the FREE switch, or operate the SELECTOR switch on the EM right control panel. When the FREE switch is turned off, the lens system returns to the state set before the switch was turned on, and when the SELECTOR switch is operated, the lens system returns to the state according to the magnification (or camera length) selected by the switch.

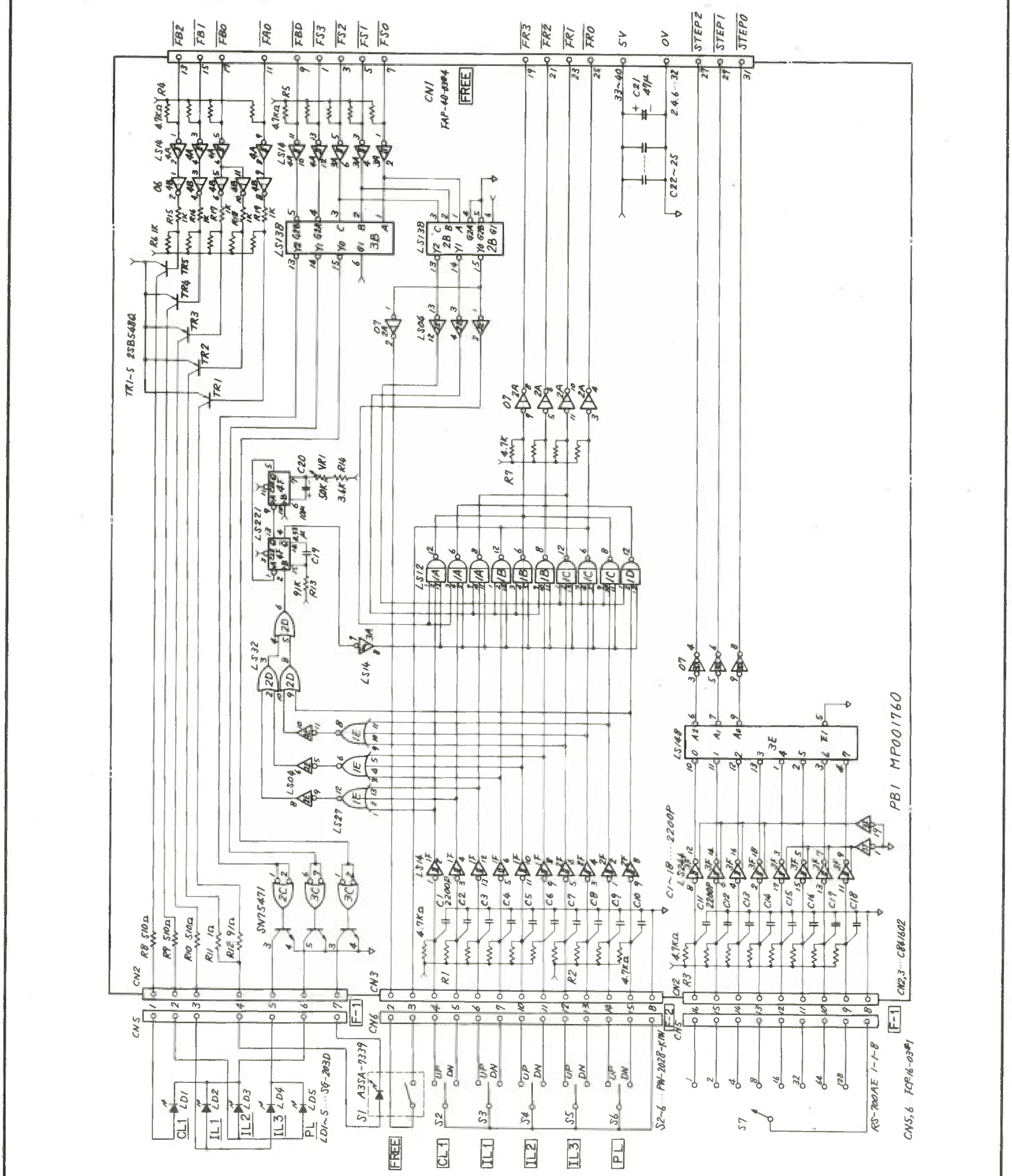
COMPONENTS LIST (BE520)

K-NO. 82,03,03
606101641(00) MODEL EM-FLC10 EM568001-

PART NO.	DESCRIPTION		PAGE
606112413	606112413(C0)-00 4	CABLE	1
606143963	606143963(00)-00 3	FREE CONT UNIT	2
606143971	606143971(C0)-C0 3	FC ITF PB	3

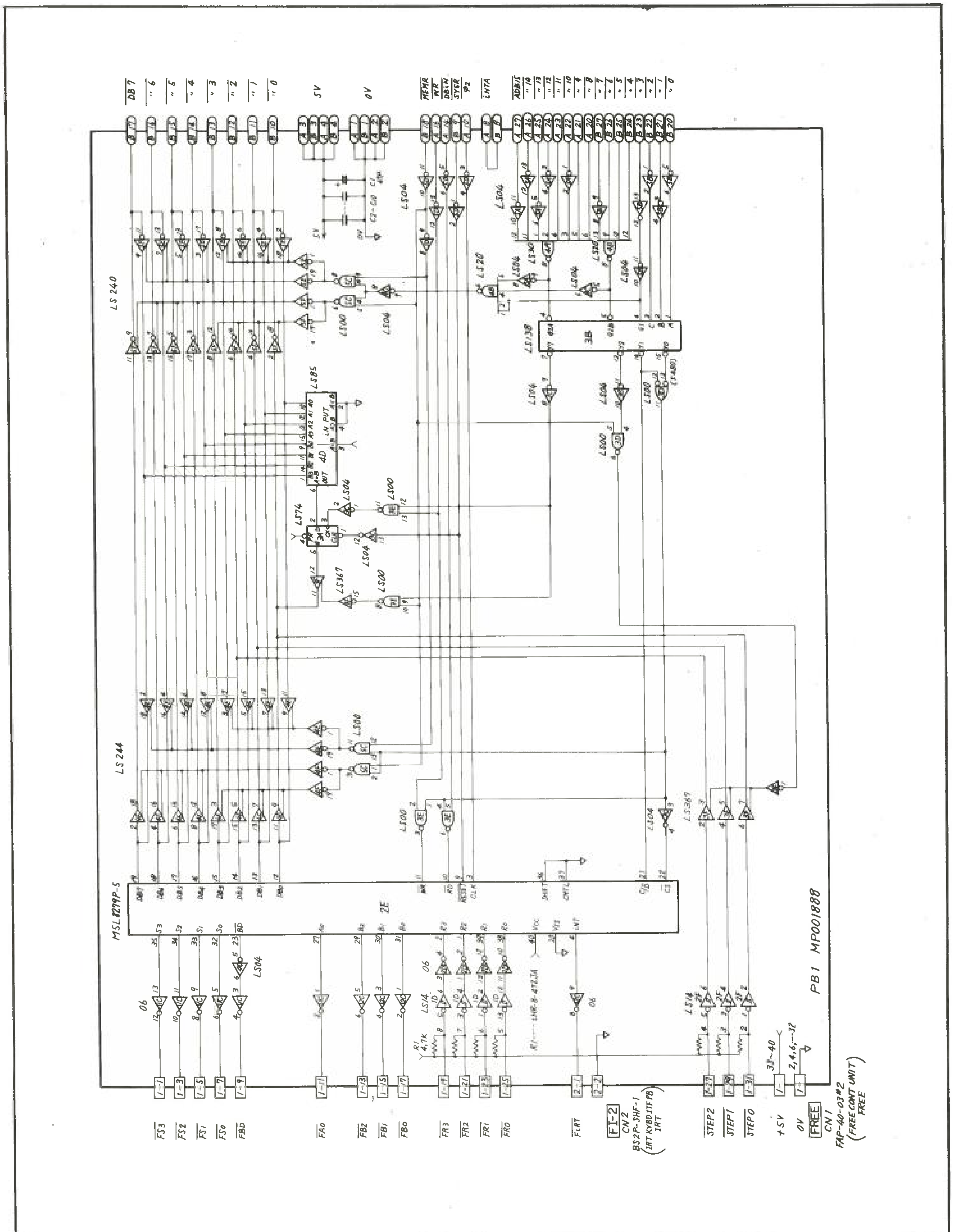


CABLE	606112413



FREE CONT UNIT

606143963



FC ITF PB

606143971

INSTRUCTIONS

EM-PRT10

P R I N T E R

No. IEM1200EX-PRT10
(EM569001)

1. GENERAL

This printer is used for printing out all the information displayed on the CRT of the electron microscope (EM) operation panel.

2. SPECIFICATIONS

∘ Type:	Non-impact type.
∘ Printing characters:	7 × 5 dots matrix.
∘ Number of characters:	31 characters/line.
∘ Printing speed:	Aproximately 2 lines/sec.
∘ Paper:	60 × 30 mm, metalized paper (SILVERNO 890-2B: Honshu Seishi, or Bosch RMP8146, 24 V: Robert Bosch GMBH).
∘ Dimensions:	105 (W) × 145 (H) × 200 (D) mm.

3. COMPOSITION

- Printer
- Cables (2)
- Paper

4. INSTALLATION

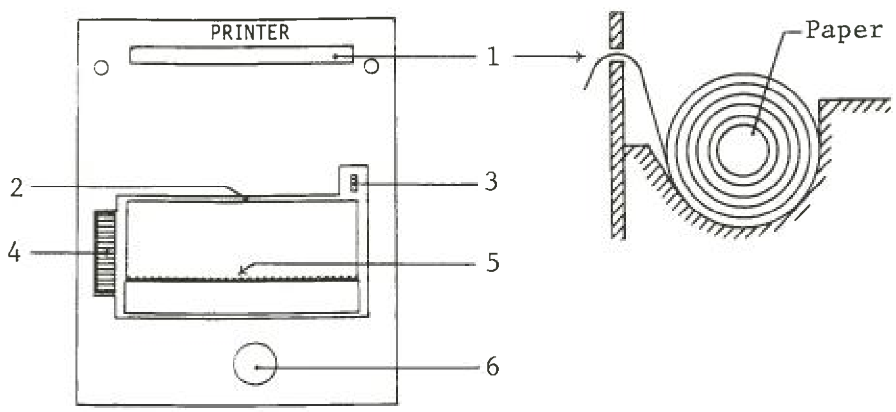
1. Turn off the EM and insert the printer into the left-most position on the left control panel (L1).
2. Connect the two cables, one to the connector (PRI) of the PRINTER ITF PB in the card rack (rear of right console), and the other to the connector (PS5) of the POWER SUPPLY UNIT in the rear of the left console.

5. OPERATIONS

Push the RPINT key on the keyboard to print out the information on the CRT. To stop the printing out halfway, push the ESC key.
Note: Figures cannot be printed out.

6. PAPER LOADING (see figure)

1. With knob 6 pulled out, draw out the printer.
2. Mount paper on the printer and pull out paper end through slit 1.



3. Insert paper end into slit 2 and turn knob 4 upward until paper end shows through slit 5.
   Note: Paper can be freely pulled out through slit 5 when lever 3 is pushed down.
4. Replace the printer.

COMPONENTS LIST (BE520)

K-NO. 82,03,03
606101632(00) MODEL EM-PRT10 EM569001-

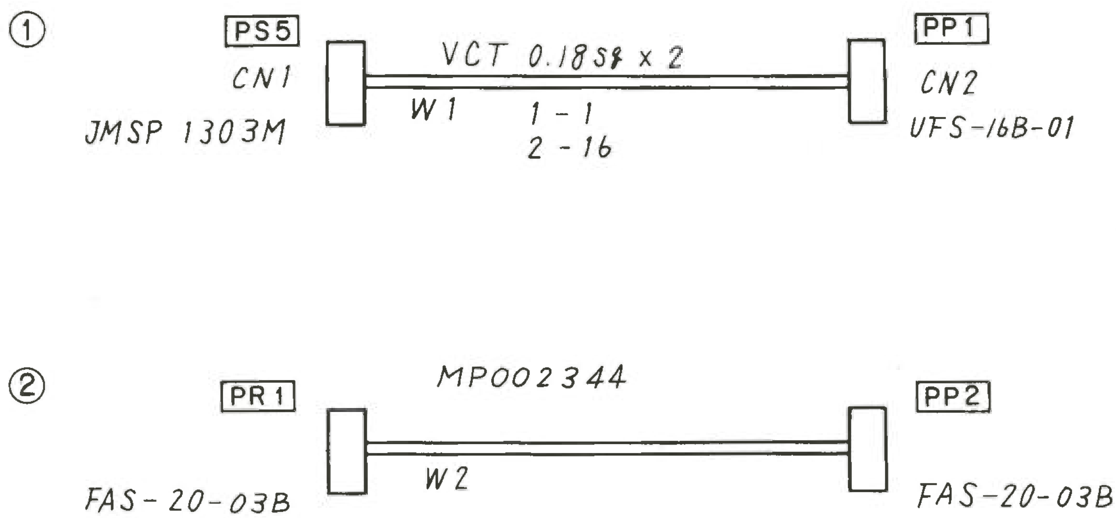
PART NO.	DESCRIPTION		PAGE
606114343	606114343(00)-00 4	CABLES	1
606111883	606111883(01)-01 4	PRINTER UNIT	2
606111891	606111891(02)-02 4	PTR DRIVER PB	3

N O T I C E

In order to keep abreast of the latest technological developments, the circuits and circuit components constituting your recently delivered instrument may differ slightly from those as indicated in your book of circuit diagrams.

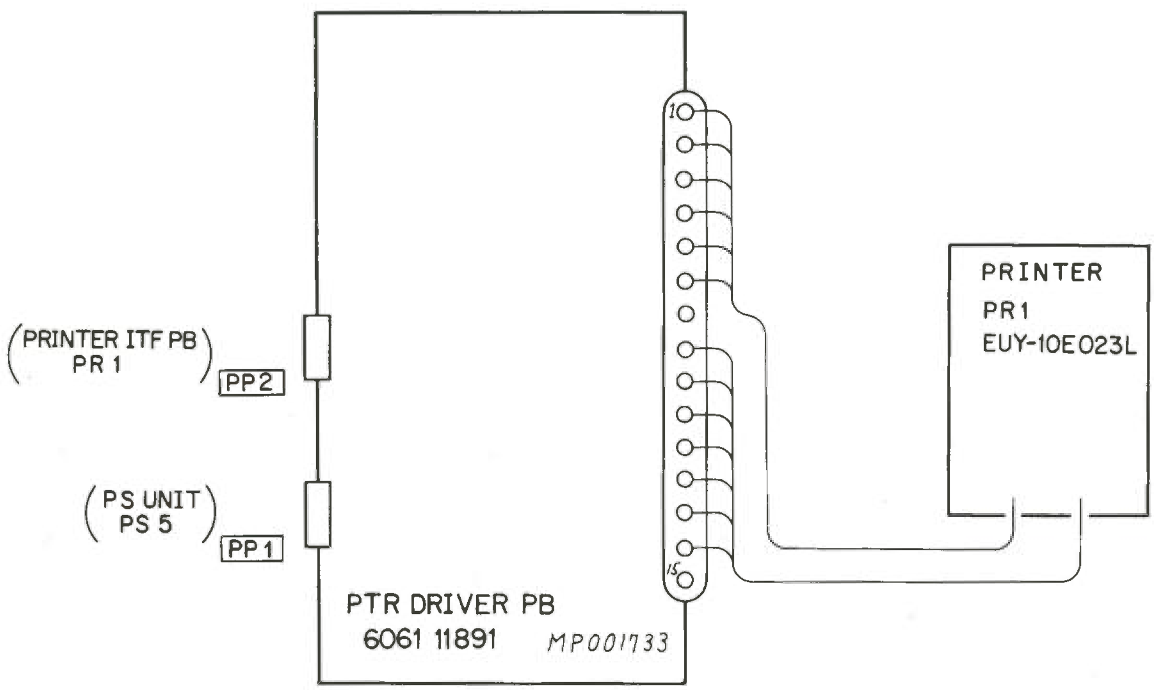
この電気回路図を使用していただくにあたって

最新のエレクトロニクスが要求される理科学機器の性質上，本装置では常に改良が加えられています。したがって，貴所に納入されました装置の実際の回路とこの回路図では数値その他に多少の差異が生ずることがありますが，その点御理解の上御了承願います。

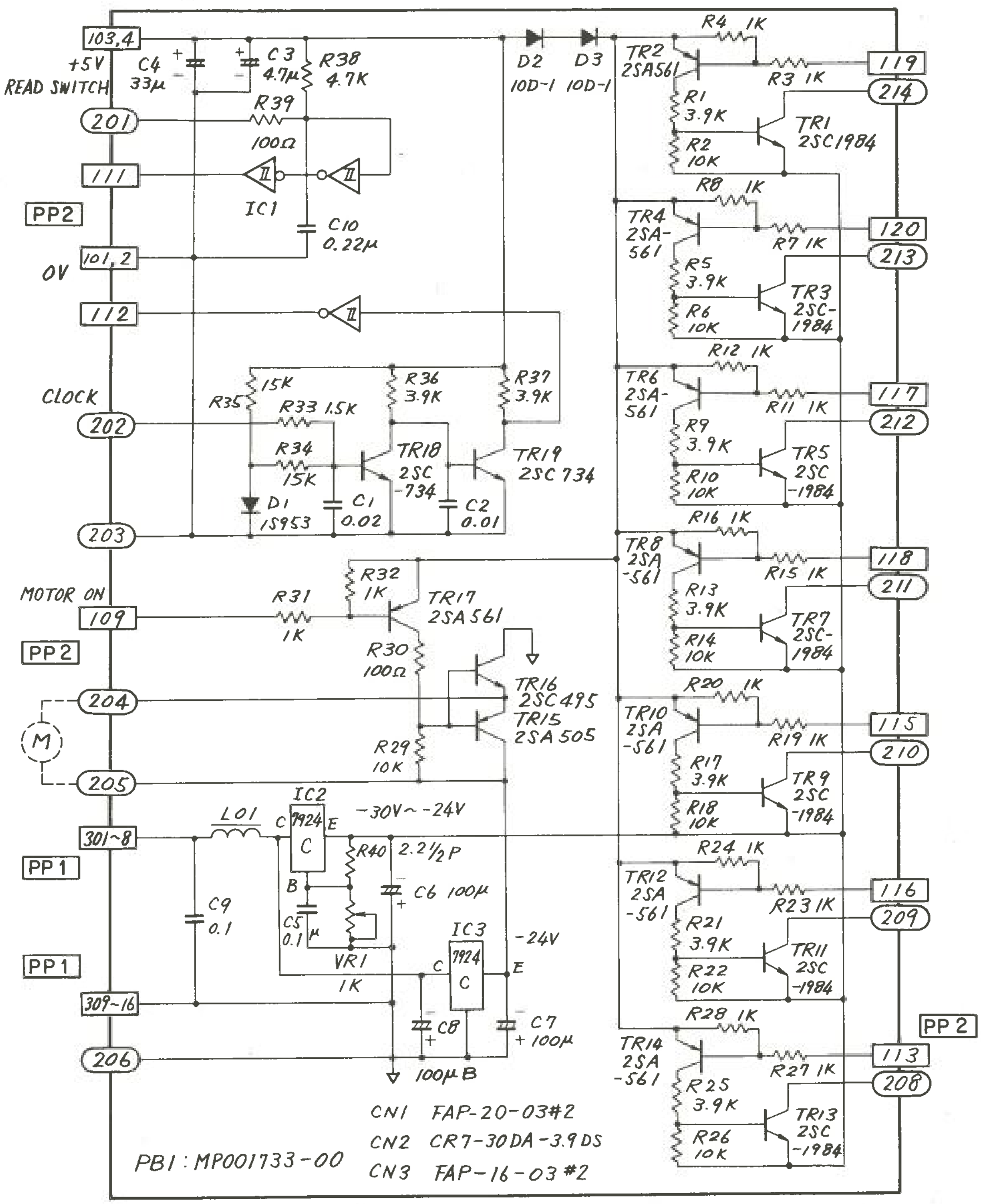


CABLES

606114343



PRINTER UNIT | 606111883



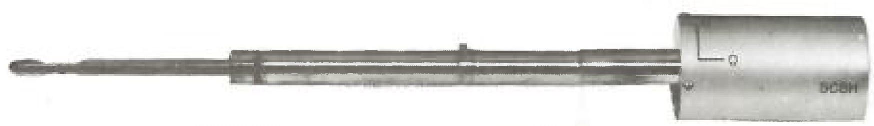
PTR DRIVER PB	606111891

INSTRUCTIONS

EM-SCSH

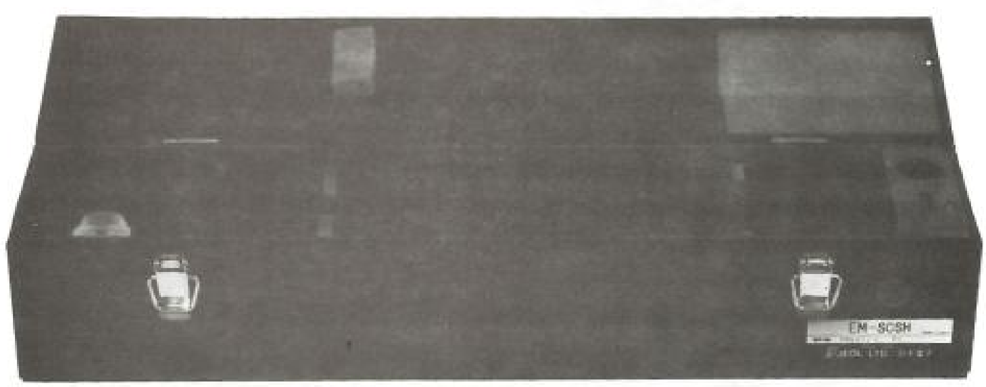
COMMON SPECIMEN HOLDER

No. IEM100CX-SCSH-2
(EM709153)



Common specimen holder


Protection cylinder



Specimen holder box

1. WHEN USED WITH THE EM-QR QUICK CHANGE SPECIMEN RETAINER

1. 1 General

The use of the EM-QR quick change specimen retainer with the EM-SCSH common specimen holder in a JEM electron microscope equipped with an EM-SEG side entry goniometer will greatly simplify specimen exchange and provide the capability for observation of tilted specimens.

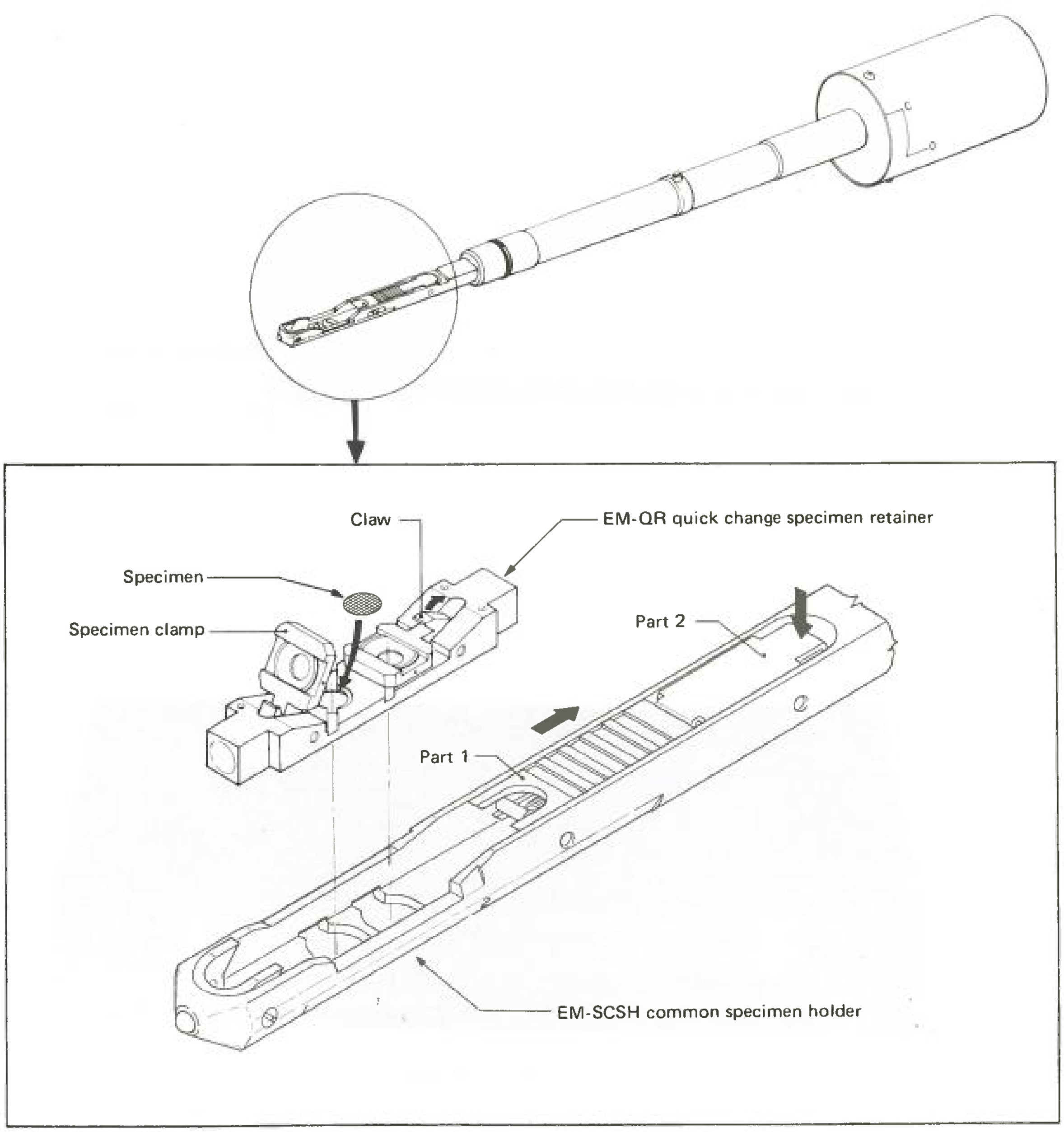


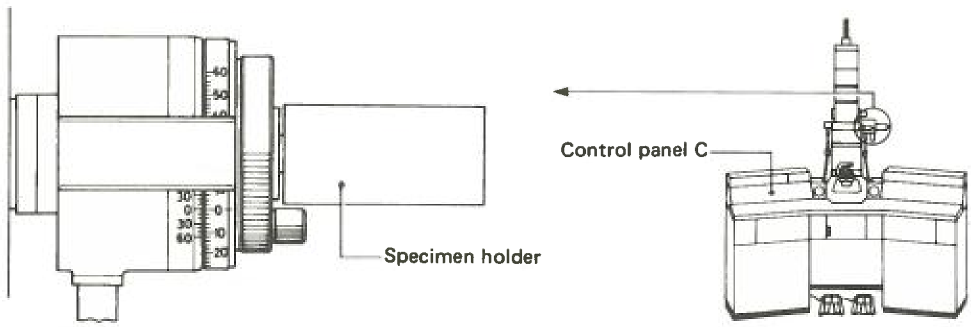
Fig. 1 EM-QR quick change specimen retainer and EM-SCSH common specimen holder

1. 2 Specifications

Guaranteed resolution:	2 Å (lattice), 5 Å (point)
Specimen tilt angle:	Single axis tilt, ±60°
Specimen tilt speed:	9°/min. ~ 90°/min.
Retainer capacity:	2 specimens

1. 3 Extracting the specimen holder from the column

1. Turn the FILAMENT EMISSION knob (control panel C) to OFF.
2. Pull out the EM-SCSH specimen holder, turn it fully counterclockwise, and then remove it.



3. Cover the specimen holder with the protection cylinder and store it in the specimen holder box.

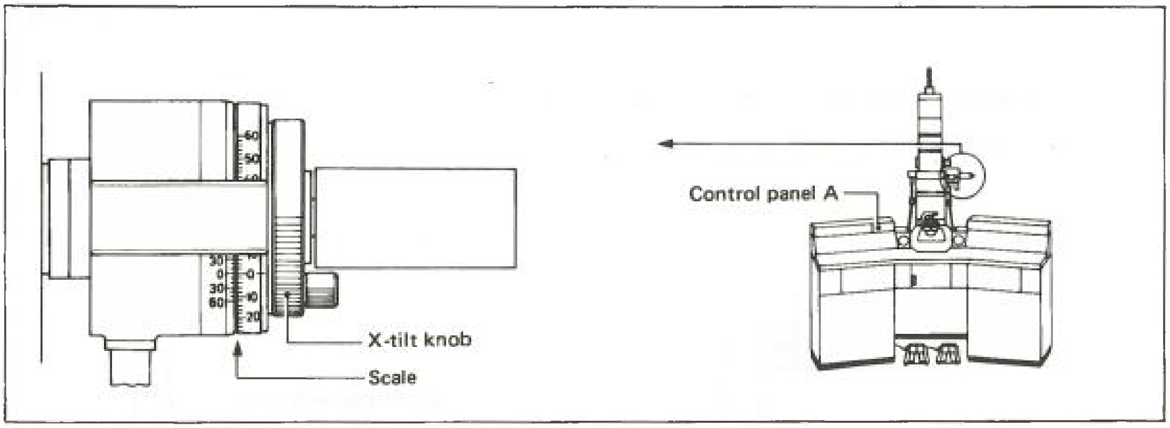
1. 4 Loading a specimen into the specimen holder

1. With the specimen holder in the specimen holder box, move part 1 in the direction indicated by the arrow until it stops. Then remove the specimen retainer from the specimen holder (see Fig. 1).
2. Move the claw in the direction indicated by the arrow (Fig. 1) in order to raise the specimen clamp.
3. Insert the specimen and lower the specimen clamp to its original position. Record the type of specimen and the specimen number indicated on the side of the holder.
4. With the specimen retainer in the specimen holder, push part 2 in the direction indicated by the arrow (Fig. 1). The specimen retainer is thereby secured.

1. 5 Inserting the specimen holder into the column

1. Limit the X-tilt angle to 60°.

1a. After turning the X knob (control panel A) fully clockwise, set the X-tilt knob scale to 0 by operating the X pedal switches.



1b. Set the two X-tilt angle limiting screws (Fig. 2) to 60°.

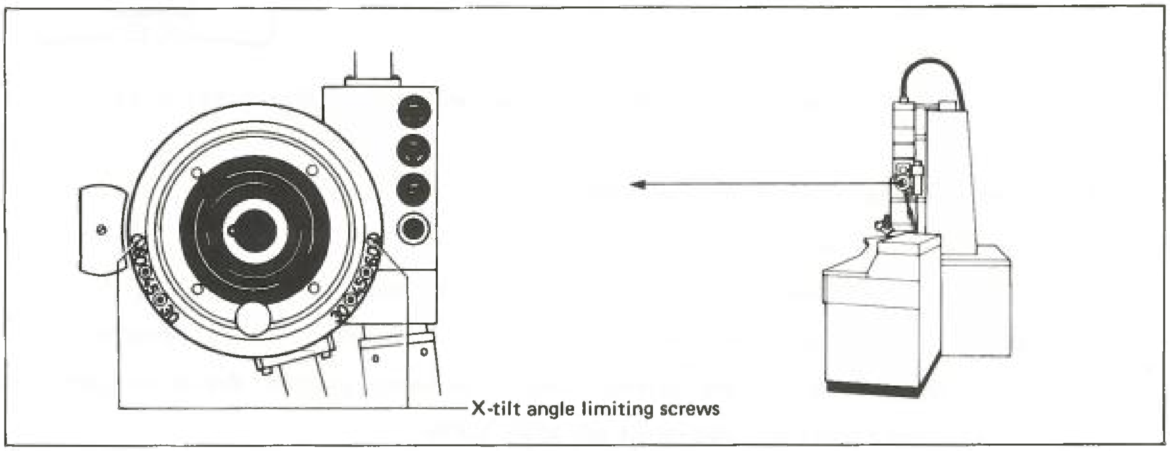
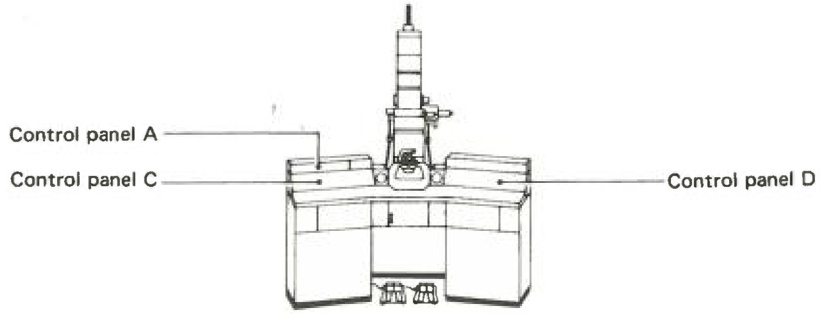


Fig. 2 X-tilt angle limiting screws

2. Confirm the following:

2a. The HIGH lamp (control panel A) and the AIRLOCK OPEN lamp (control panel D) are lit.

2b. The FILAMENT EMISSION knob (control panel C) is OFF.



3. After checking that there is no dirt or dust on the O-ring of the specimen holder, match the guide pin of the specimen holder with the guide groove of goniometer (Fig. 3), insert the holder into the goniometer until it stops (the lamp on the connector box lights up and evacuation of the goniometer begins). Push the specimen holder against the goniometer until the connector box lamp goes out.

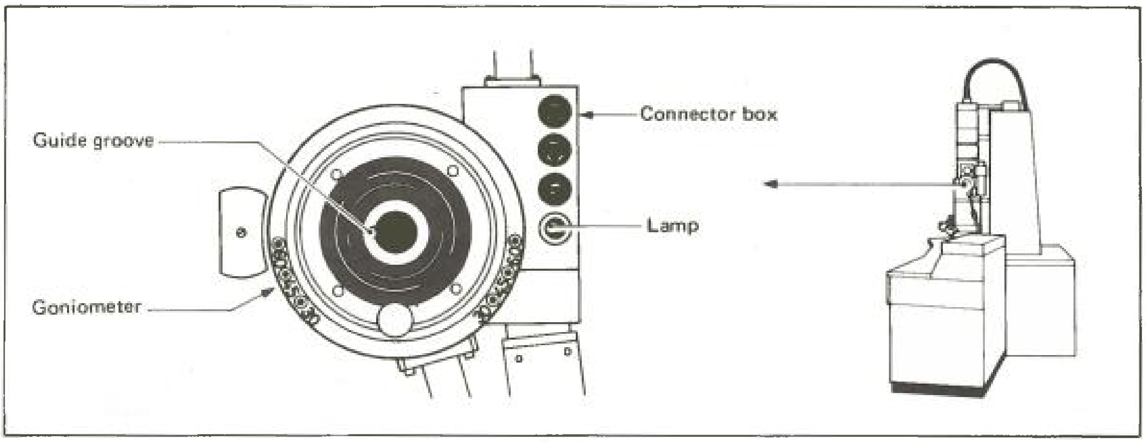


Fig. 3 Goniometer and connector box

4. When the connector box lamp goes out (that is, when evacuation of the goniometer is finished), turn the specimen holder clockwise and push it all the way in.
5. Set the specimen number indicator to the desired specimen number (refer to Step 4, Section 1. 3) with the specimen selector (Fig. 4).

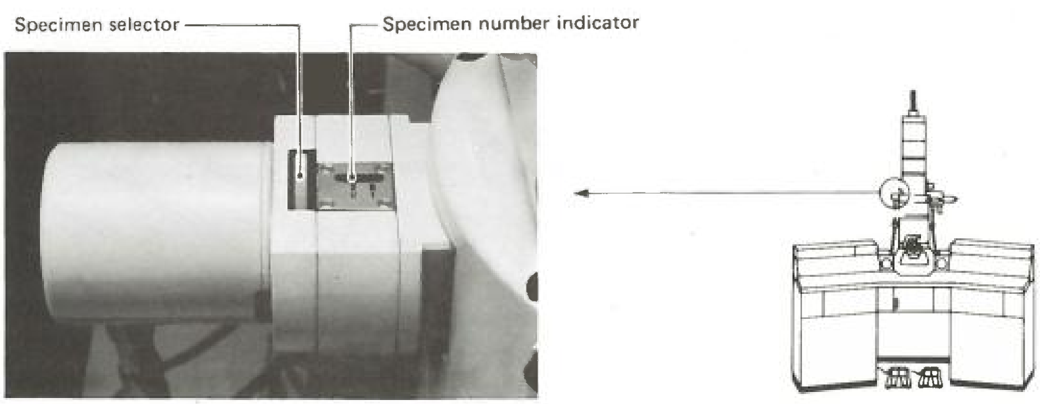


Fig. 4 Specimen selector

2. WHEN USED WITH THE EM-BR BULK SPECIMEN RETAINER

2. 1 General

The use of the EM-BR bulk specimen retainer with the EM-SCSH common specimen holder in a JEM electron microscope equipped with an EM-SEG side entry goniometer and EM-ASID scanning image observation device allows the secondary electron image of a bulk specimen to be observed. Refer to "EM-ASID Instruction Manual" to observe secondary electron images.

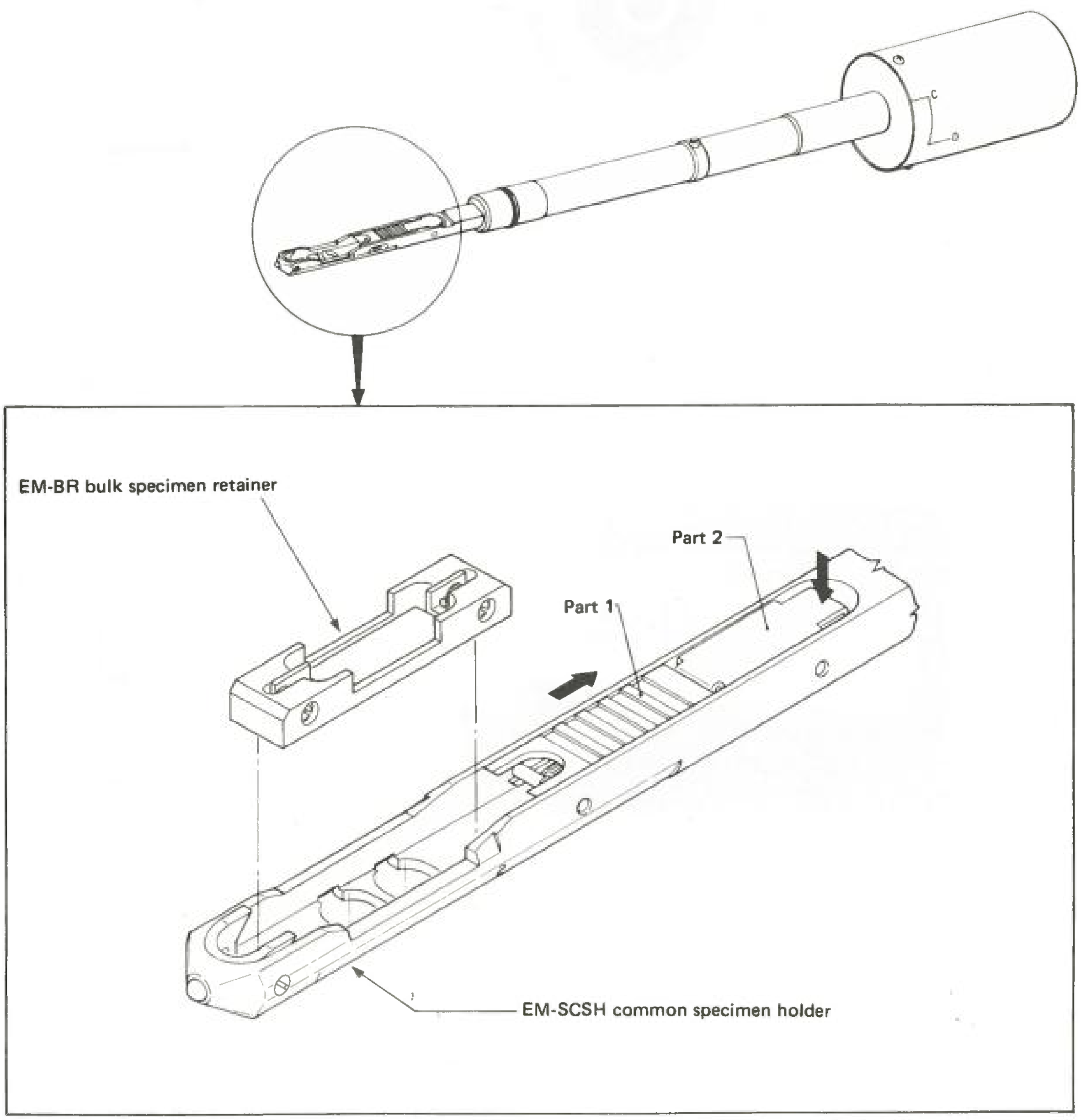


Fig. 5 EM-BR bulk specimen retainer and EM-SCSH common specimen holder

2. 2 Specifications

Specimen tilt angle:	Single axis tilt, $\pm 60^\circ$
Specimen tilt speed:	9°/min. ~ 90°/min.
Specimen size:	Less than 13.5 mm $\times$ 4.5 mm $\times$ 3.3 mm (thickness)

2. 3 Extracting the specimen holder from the column

Refer to Section 1. 3.

2. 4 Loading a specimen into the specimen holder

1. With the specimen holder in the specimen holder box, move part 1 in the direction indicated by the arrow until it stops. Then remove the specimen retainer from the specimen holder (Fig. 5).
2. Loosen screws A (two) on the frame of the specimen retainer and take the plate out of the frame (Fig. 6).

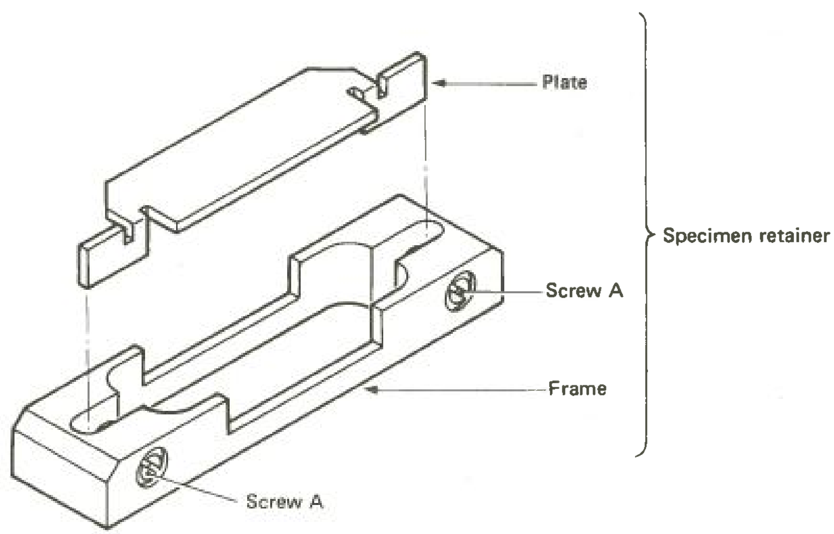


Fig. 6 EM-BR bulk specimen retainer

3. Prepare a specimen measuring less than 13.5 $\times$ 4.5 $\times$ 3.3 (thick) mm. If the specimen thickness is between 1.6 mm and 3.3 mm, bond the specimen to face A of the plate with conductive adhesive; and if the thickness is less than 1.6 mm, to face B (Fig. 7).

   Note: To make the specimen surface coincide with the tilt axis, bond the specimen to face A; however, the specimen thickness must be less than 1.0 mm.

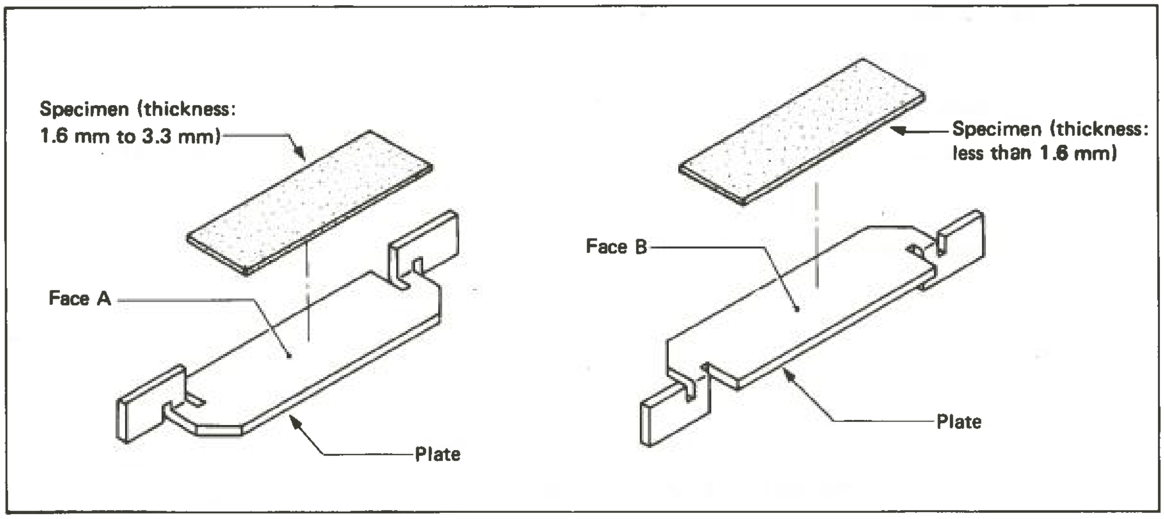


Fig. 7 Attaching the specimen

4. Place the frame so that its lower face contacts the bottom of the specimen height adjusting jig, and then secure it with screw B (Fig. 8).

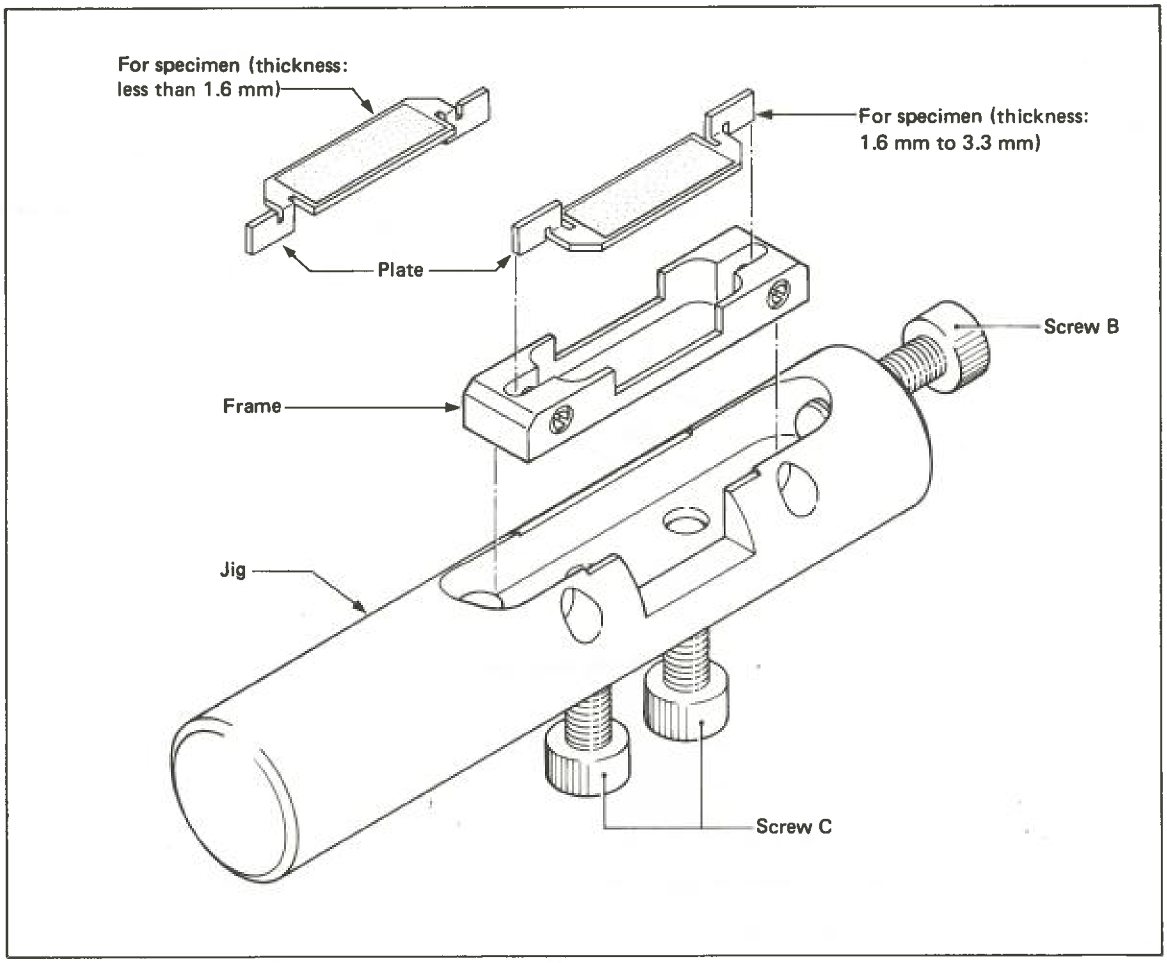


Fig. 8 Attaching the frame to the specimen height adjusting jig

5. Set the plate into the frame with the specimen facing up (Fig. 8).
6. Position the specimen surface flush with face D (upper face of the specimen height adjusting jig) with screw C (Fig. 9).

   Note: To make the specimen surface coincide with the tilt axis, align the specimen surface with face E (the upper face of the specimen retainer); however, the specimen thickness must be less than 1.0 mm.

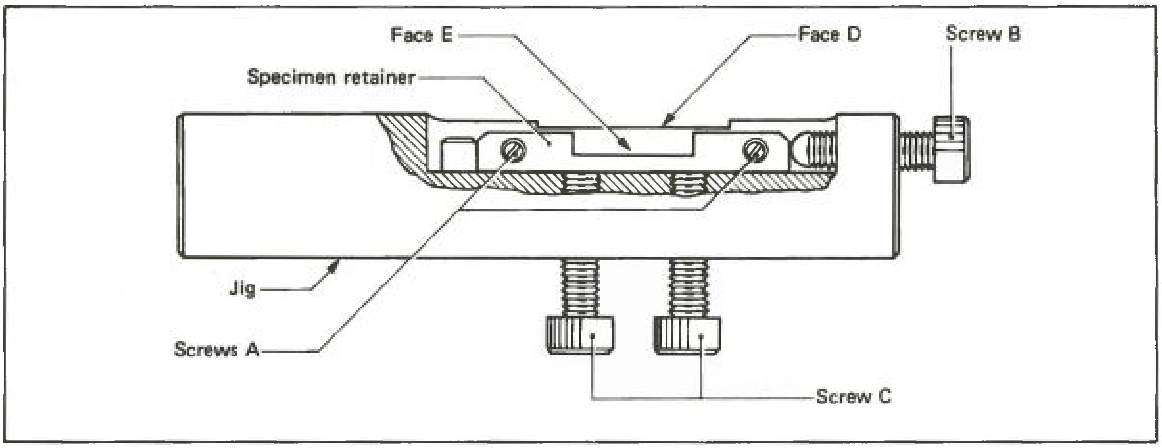


Fig. 9 Specimen height adjustment

7. After securing the plate to the frame with screws A (Fig. 9), loosen screw B and take the EM-BR out of the jig.
8. Place the specimen retainer in the specimen holder and push part 2 in the direction of the arrow (Fig. 5) in order to secure it.

2. 5 Inserting the specimen holder into the column

Refer to Section 1. 5.

3. WHEN USED WITH THE EM-SR GRAPHITE SPECIMEN RETAINER

3. 1 General

The use of an EM-SR graphite specimen retainer with the EM-SCSH common specimen holder in a JEM electron microscope equipped with the EM-ASID scanning image observation device and the NDS energy dispersive X-ray spectrometer permits X-ray analysis of microareas of the specimen.

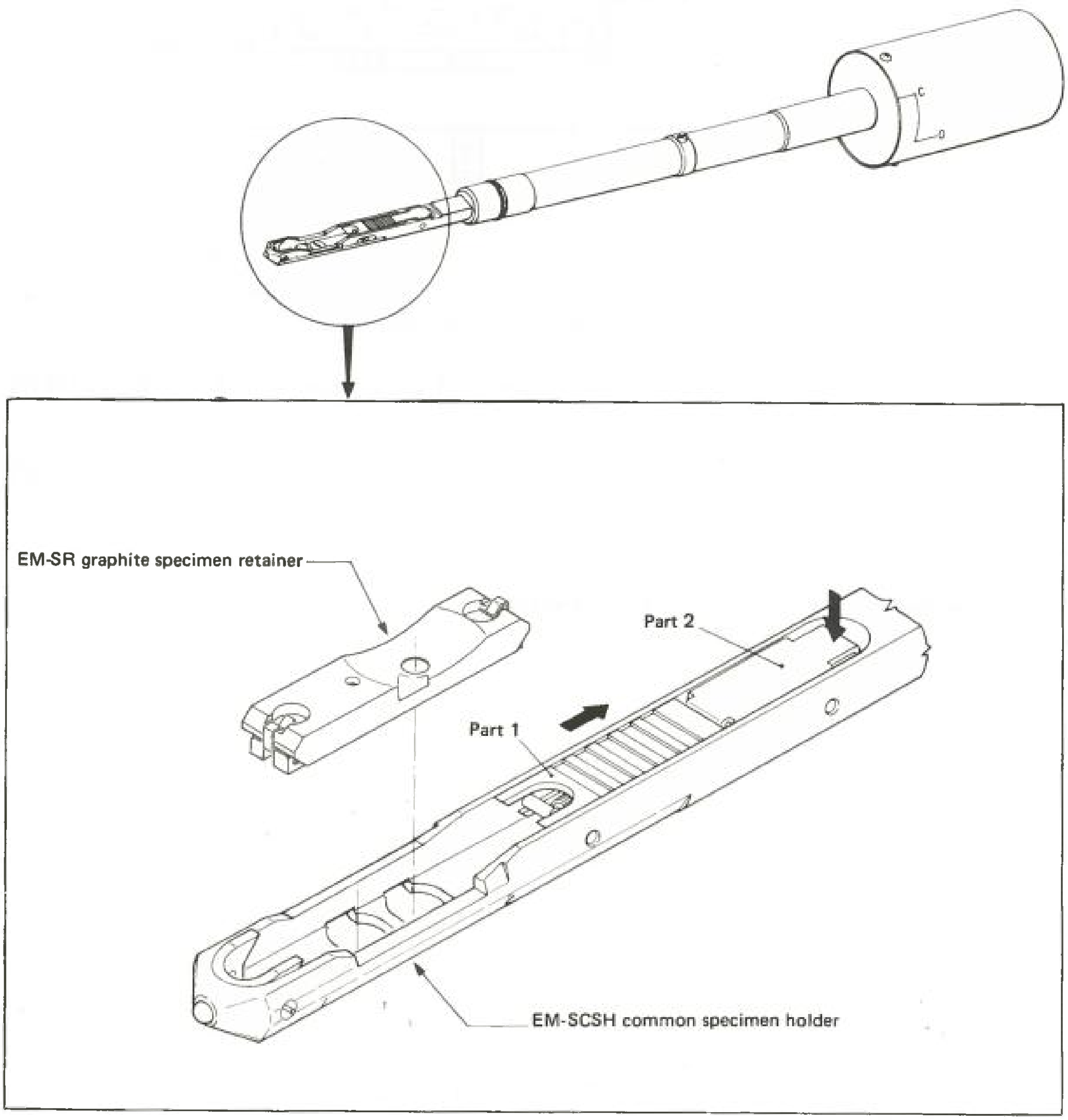


Fig. 10 EM-SR graphite specimen retainer and EM-SCSH common specimen holder

3. 2 Extracting the specimen holder from the column

Refer to Section 1. 3.

3. 3 Loading a specimen into the specimen holder

1. With the specimen holder in the specimen holder box, move part 1 in the direction of the arrow until it stops. Then remove the specimen retainer from the specimen holder (Fig. 10).
2. Remove the plate springs from both sides of the specimen retainer and separate the upper and lower parts (Fig. 11).

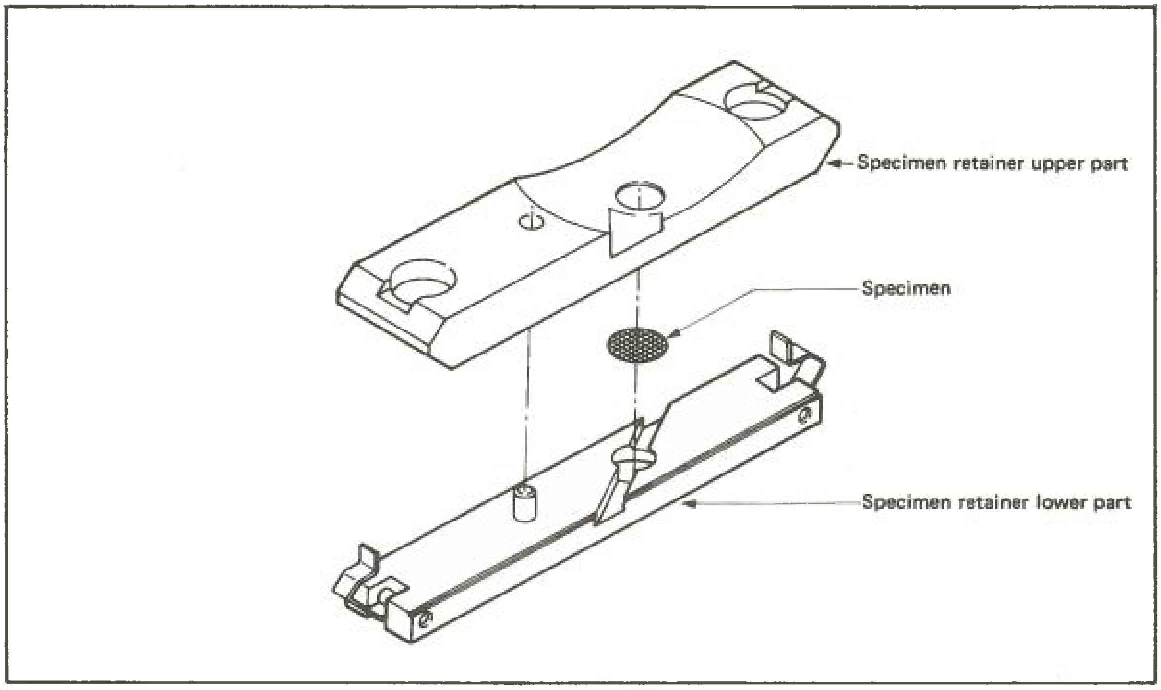


Fig. 11 Specimen retainer parts

3. Place the specimen in the lower part of the retainer and then attach the upper part with the plate springs.
4. Put the specimen retainer into the specimen holder and push part 2 in the direction indicated by the arrow (Fig. 10). The specimen plate is thereby secured.

3. 4 Inserting the specimen holder into the column

Refer to Section 1. 5.

INSTRUCTIONS

EM-SRH10

SPECIMEN ROTATING HOLDER

No. IEM-SRH10
(EM567001)

1. GENERAL

The used of the EM-SRH specimen rotating holder in a JEM electron microscope equipped with a side entry goniometer enables specimens to be tilted as well as rotated.

2. SPECIFICATIONS

◦ Specimen tilt angle: (single tilt)	±25° with SHP.
	±30° with HMP.
	±60° with SAP.
◦ Rotation angle:	±180°.
◦ Specimen grid:	3 mm dia. grid.
◦ Effective field of view:	2 mm dia. (at tilt angle 0°).

3. COMPOSITION (Fig. 3.1)

1. Specimen holder box
2. Specimen holder (incl. protection cylinder)
3. Specimen holder stand
4. Specimen exchange mount A
5. Specimen clamp
6. Specimen exchange mount B
7. Specimen exchange tool

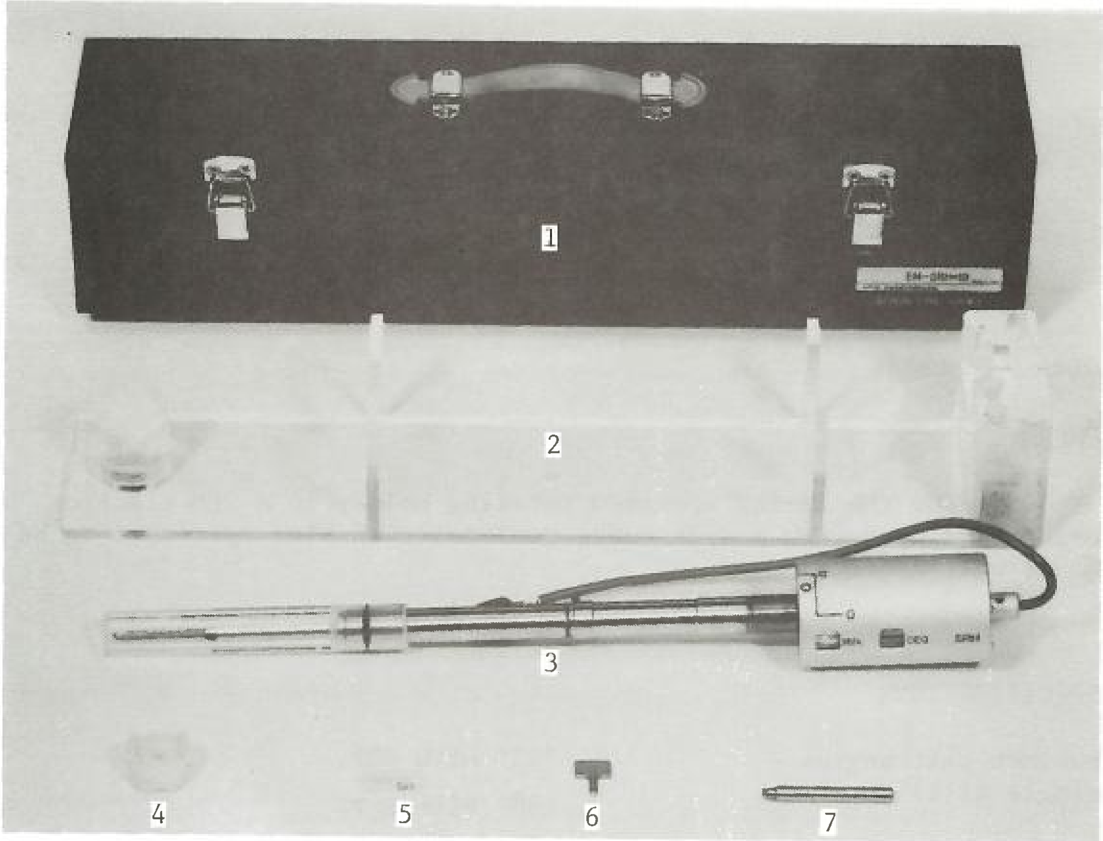


Fig. 3.1 Composition

4. OPERATION

4.1 Removing the specimen holder from the column

1. Set the FILAMENT (EMISSION) knob to OFF.
2. Disconnect the specimen holder cable.
3. Withdraw the specimen holder as far as it will go, turn it fully counterclockwise, and remove it.
4. Cover the specimen holder with the protection cylinder and store it in the specimen holder box.

4.2 Specimen exchange

1. Remove the specimen holder stand from the specimen holder box and mount specimen exchange mount B on specimen exchange mount A (see Fig. 4.1).

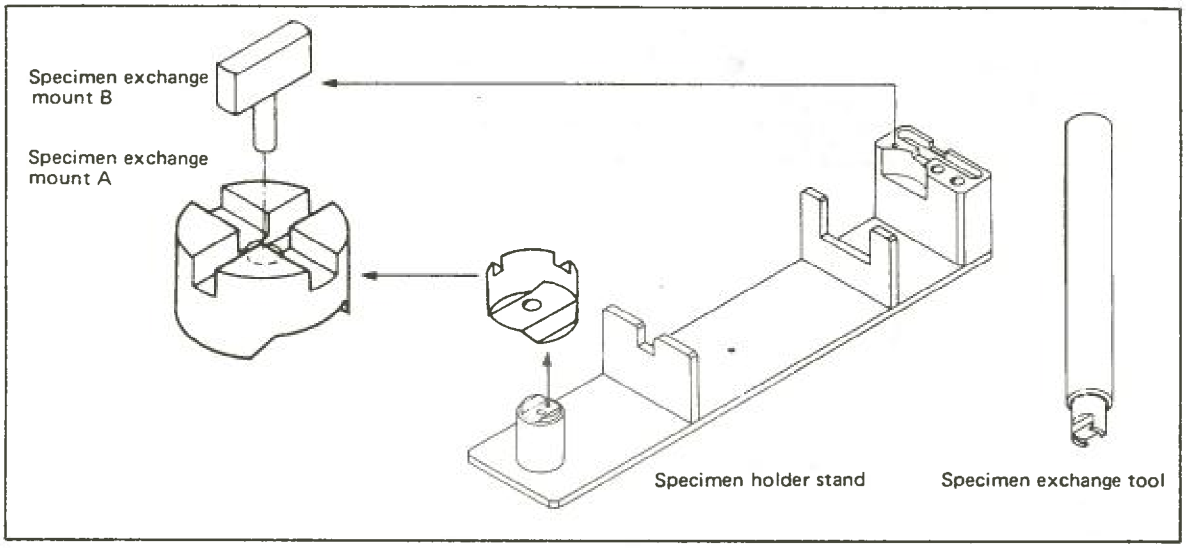


Fig. 4.1 Specimen exchange mounts

2. Place specimen exchange mount A in the specimen holder stand so that mount B is oriented as shown in Fig. 4.2.

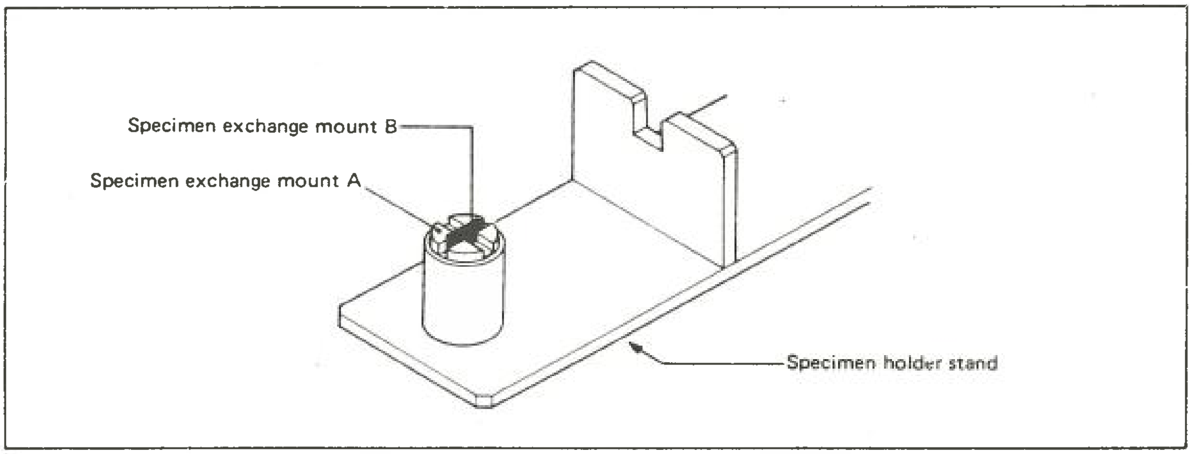


Fig. 4.2 Mounting the specimen exchange mounts

3. Place the specimen holder on the specimen holder stand with the holder shaft pin facing downward as shown in Fig. 4.3.

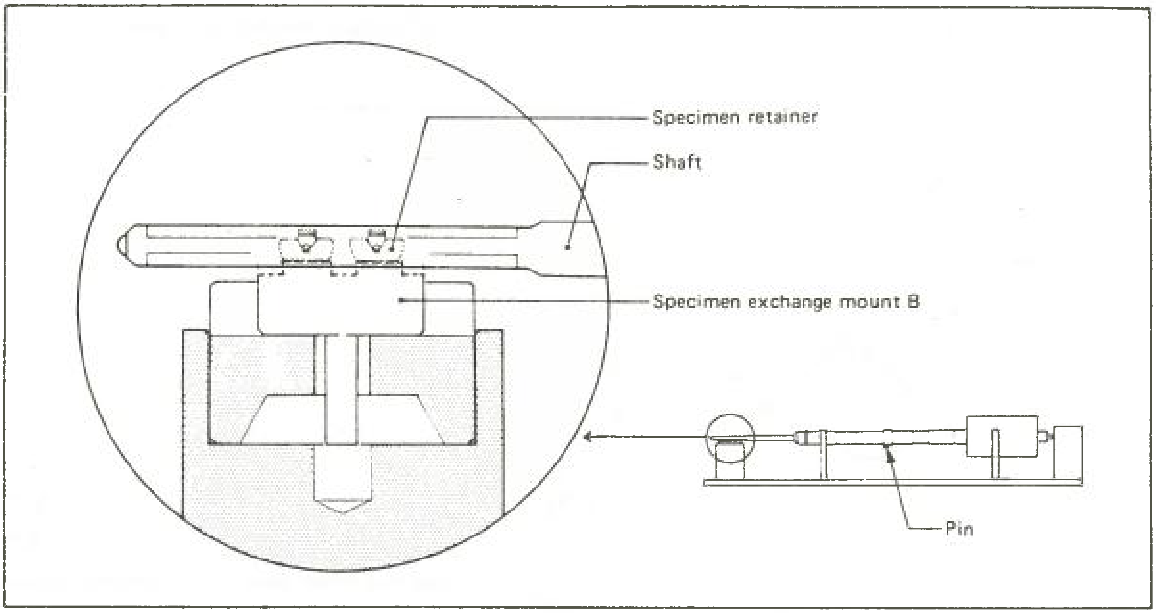


Fig. 4.3 Mounting the specimen holder on the holder stand

4. Remove the used specimen from the specimen holder as follows (Fig. 4.4):
   a. Orientate the clawed tip of the specimen exchange tool in the

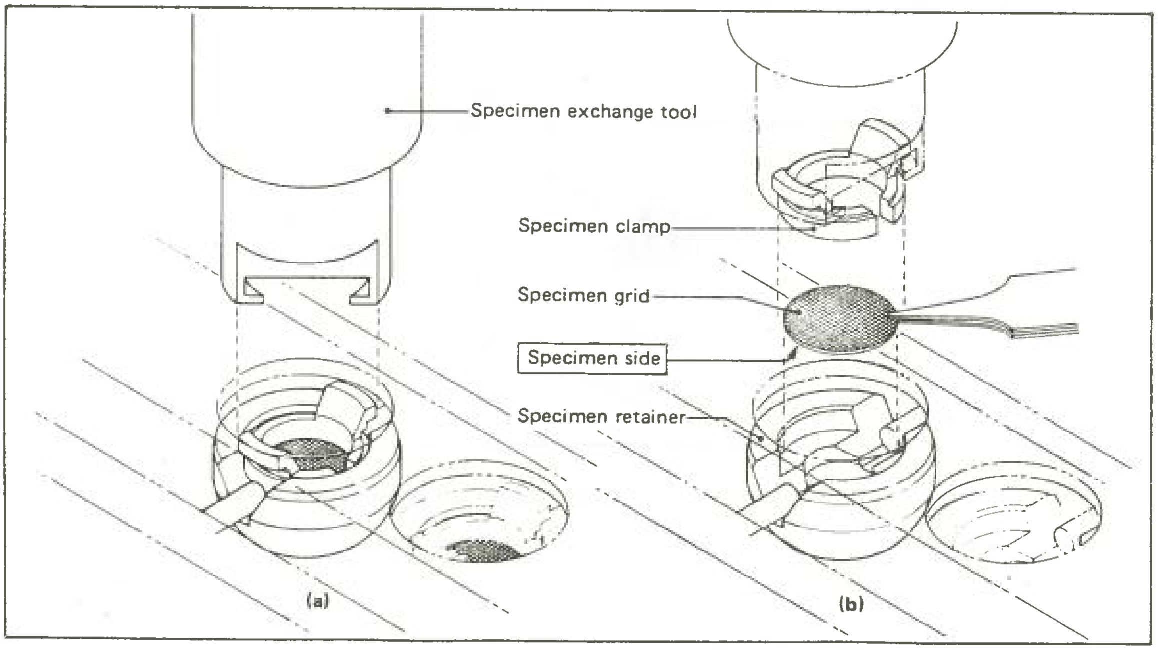


Fig. 4.4 Specimen exchange

specimen retainer so that the two claws do not align with the arms of the specimen clamp (Fig. 4.4a), then, while lightly applying downward pressure on the tool, turn the tool so that it engages with the tipped rim of the clamp and remove the clamp by lifting the tool straight up (Fig. 4.4b).

b. Remove the specimen holder from the holder stand, and the specimen from the holder by turning the holder upside down.

c. Return the specimen holder to the stand (Fig. 4.3).

5. Load a new specimen in the specimen holder as follows:
   a. Place the specimen grid in the specimen retainer with the specimen facing downward (Fig. 4.4b).
   b. Attach the specimen clamp to the specimen exchange tool and insert the tool into the specimen retainer.
   c. Detach the tool from the clamp by turning the tool sufficiently to disengage it from tipped rim of the clamp. The specimen is now secured in the specimen retainer.
   d. Make a note of the specimens in the 1 and 2 specimen retainers.

4.3 Inserting the specimen holder into the column

1. Limit the X-tilt angle as follows:
   a. Turn the X-tilt speed control knob fully clockwise and set the X-tilt dial to 0° by operating the X-pedal switches.
   b. Set the two X-tilt angle limiting screws (Fig. 4.5) to 25°, 30° or 60° when SAP, HMP or SAP is used, respectively.
2. Confirm the following:
   a. That the V7 of the JEM-1200EX is closed, or the HIGH and AIRLOCK OPEN lamps of the JEM-100/200CX are lit.
   b. That the FILAMENT (EMISSION) knob is set at OFF.
3. After checking that there is no dirt or dust on the specimen holder O-ring, align the specimen holder guide pin with the goniometer guide

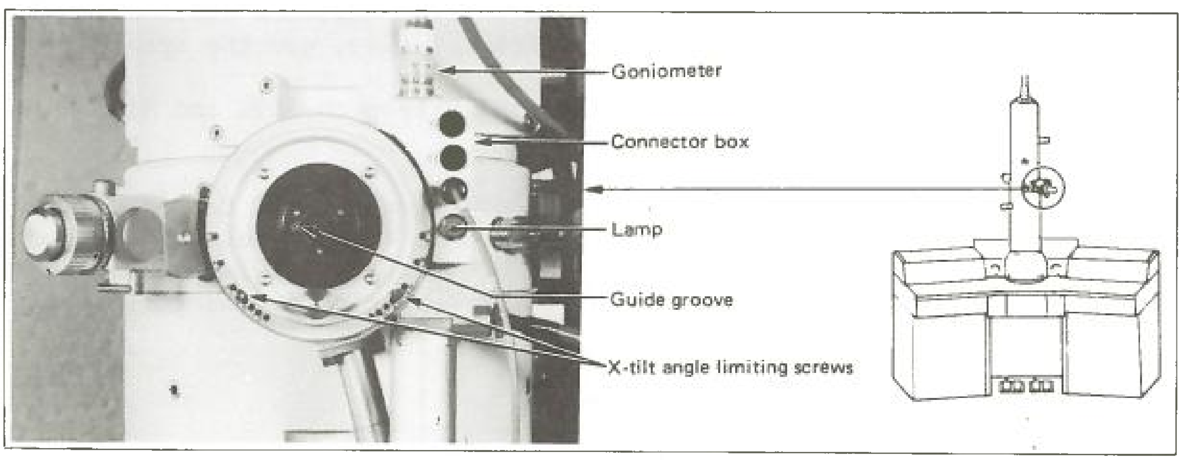


Fig. 4.5 Goniometer

groove (Fig. 4.5), push the holder into the goniometer as far as it will go and hold it there until the connector box lamp (which lights up indicating the commencement of goniometer evacuation) goes out.

4. When the connector box lamp goes out indicating that goniometer evacuation is complete, turn the specimen holder fully clockwise and push it in fully.
5. Connect the holder cable to socket H1 on the connector box.
6. Set the specimen number indicator (Fig. 4.6) to the desired number with the specimen selector.

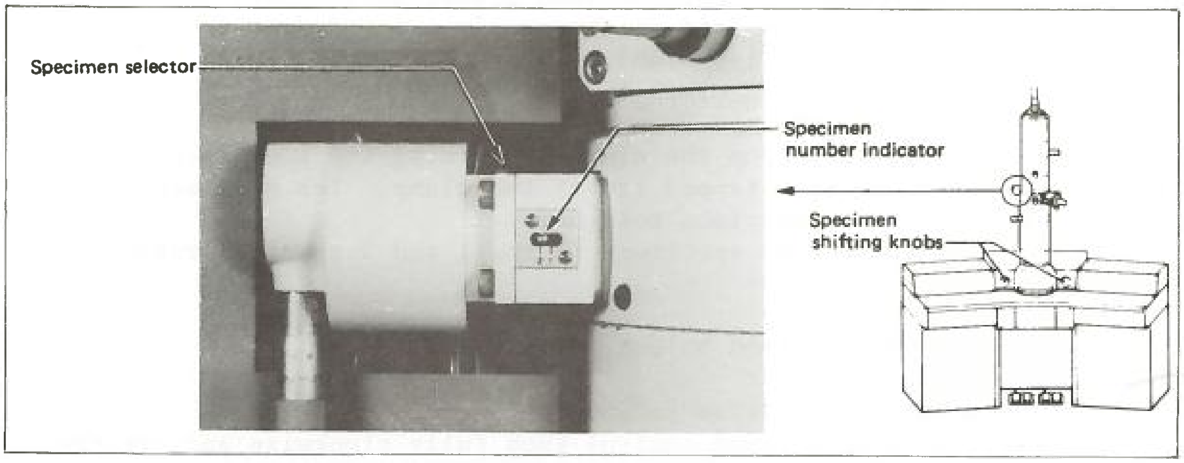


Fig. 4.6 Specimen selecting device

4.4 Specimen rotation

1. Select the desired specimen rotating speed with the Y-tilt/rotation speed control knob.
2. Rotate the specimen by operating the Y pedal switches while observing the image. To select the desired field of view, use the specimen shifting knobs.
3. If necessary, read off the rotation angle from the DEG and MIN indicators on the specimen holder.

   Reading off the rotation angle

   One graduation on the DEG indicator corresponds to 12 degrees, and one graduation on the MIN indicator corresponds to 10 minutes. The red and black digits represent rotation from 0° in the clockwise and counter-clockwise directions, respectively. For example, if the indicators read as shown in Fig. 4.7a, that is

   DEG: $96° + (12° \times 3) = 132°$

   MIN: $350' = 5°50'$,

the rotation angle is 137°50' in the clockwise direction.
If the indicators read as shown in Fig. 4.7b, that is

DEG: 48°

MIN: 330' = 5°30',

the rotation angle is 53°30' in the counterclockwise direction.

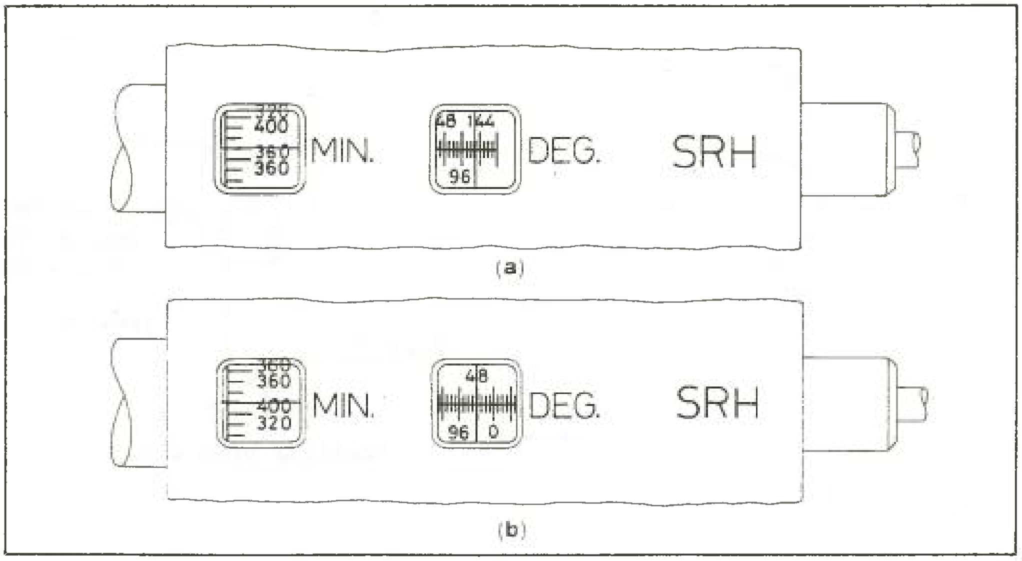


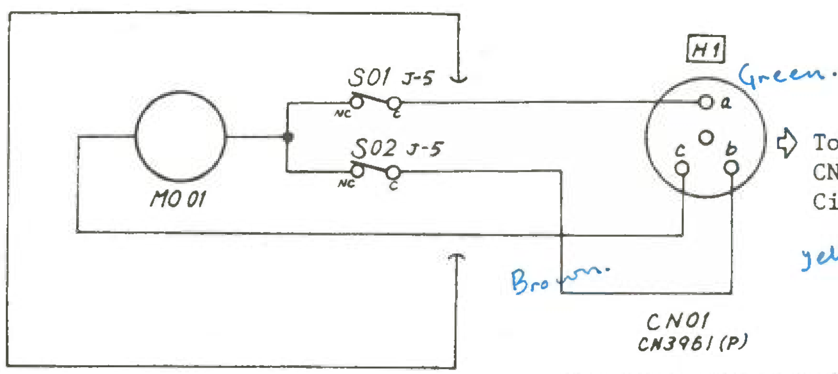
Fig. 4.7 Rotation angle indicators

Specimen tilting;

JEM-100CX: Refer to EM-SEG Instructions.

JEM-200CX: Refer to JEM-200CX Instructions.

JEM-1200EX: Refer to JEM-1200EX Instructions.



To GONIOMETER CN04 H1 (EM-SEG Circuit diagram)

(Welding side view)

SPECIMEN TILT AND ROTATION HOLDER	MT280101

INSTRUCTIONS

EM-STH10

SPECIMEN TILTING HOLDER

No. IEM-STH10
(EM566001)

1. GENERAL

The use of the EM-STH specimen tilting holder in a JEM electron microscope equipped with a side entry goniometer enables to be tilted about two orthogonal axes.

2. SPECIFICATIONS

∘ Specimen tilt angle:	±25°.
∘ Specimen grid:	3 mm dia. grid.
∘ Effective field of view:	2 mm dia. (at tilt angle 0°).

3. COMPOSITION (Fig. 3.1)

1. Specimen holder box
2. Specimen holder (incl. protection cylinder)
3. Specimen holder stand
4. Specimen exchange mount A
5. Specimen clamp
6. Specimen exchange mount B
7. Specimen exchange tool

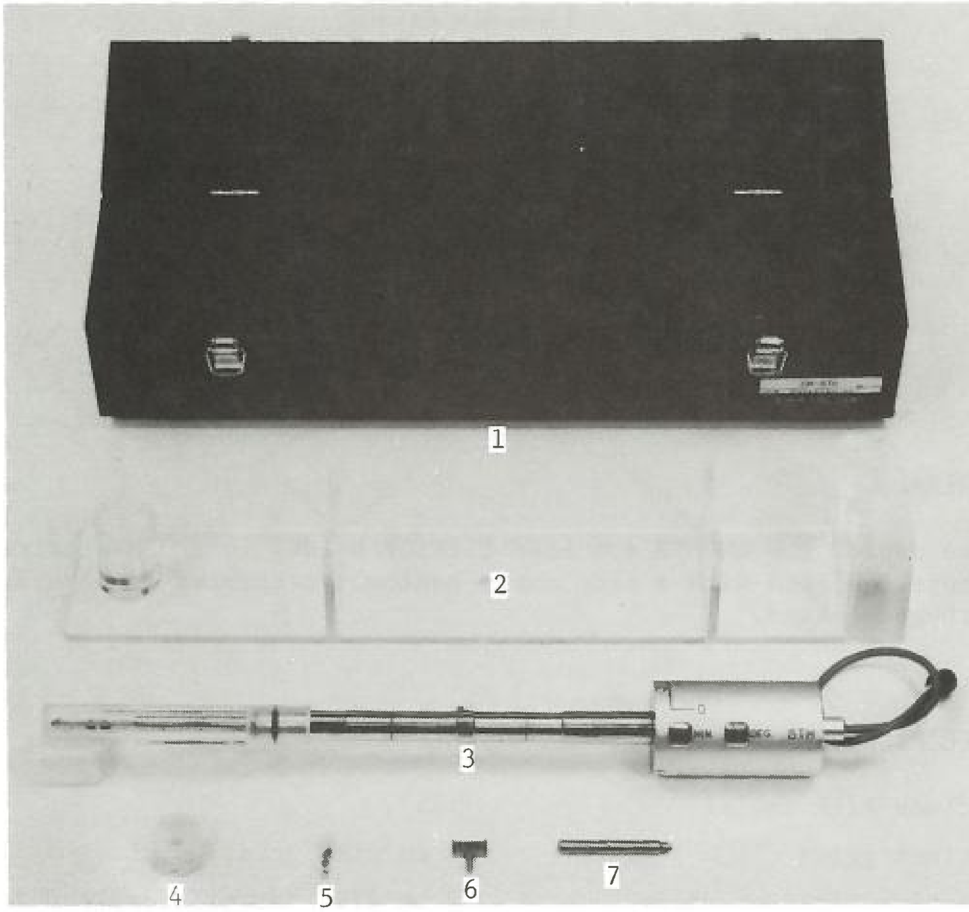


Fig. 3.1 Composition

4. OPERATION

4.1 Removing the specimen holder from the column

1. Set the FILAMENT (EMISSION) knob to OFF.
2. Select a specimen tilt speed with the Y-tilt/rotation speed control knob and use the Y pedal switches so as to obtain DEG and MIN indicator readings of 0° (see Fig. 4.1).
3. Disconnect the specimen holder cable.
4. Withdraw the specimen holder as far as it will go, turn it fully counterclockwise, and remove it.
5. Cover the specimen holder with the protection cylinder and store it in the specimen holder box.

AMENDMENTS TO INSTRUCTION MANUAL

E M - S T H 1 0

No. CI1EM-STH10
(EM566001)

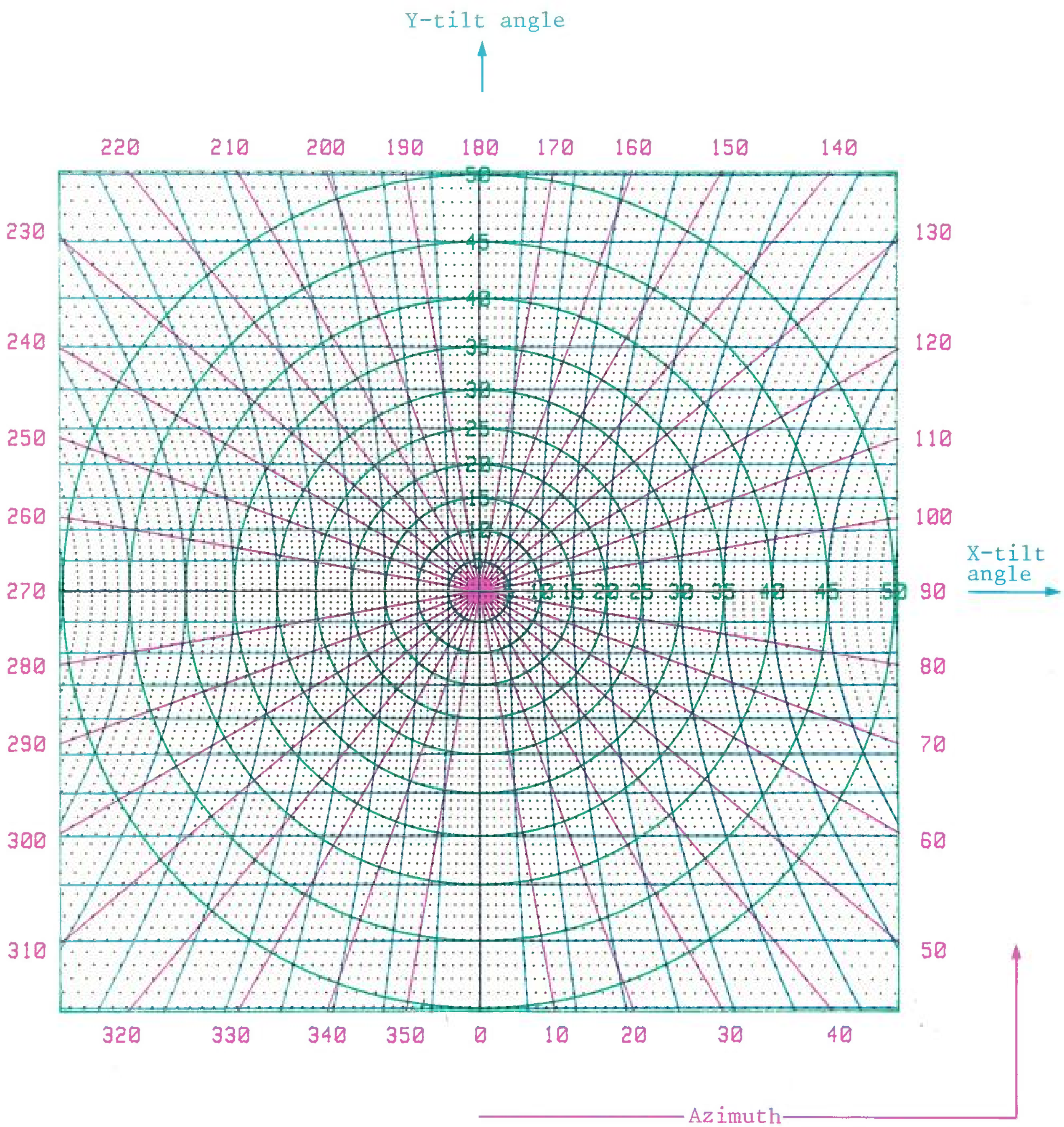
Please amend Setp 3 in Subsect. 4.4 as follows.

3. Read the Y-tilt angle from the DEG and MIN indicators on the specimen holder.
   Two turns of the MIN indicator correspond to one graduation of the DEG indicator. One turn of the MIN indicator therefore corresponds to half a graduation of the DEG indicator, 3° in other wards, one graduation of DEG indicator being 6°. One turn of the MIN indicator is graduated into 360' (6° in other wards); however, the actual specimen tilt angle when the MIN indicator is turned one rotation is 3° (180' in other wards). Consequently, the actual specimen tilt angle of one graduation of the MIN indicator is 5' although the graduation reads 10'.
   The specimen is tilted in the + (plus) direction (the red digits on the indicator should be used) if the specimen retainer (specimen) is turned counterclockwise when viewing from the column front, and in the - (minus) direction (the black digits should be used) if the retainer is turned clockwise.
   Examples: Fig. 4.8a shows the tilt angle of 17° in the - direction, i.e.,
   DEG: 12° + 3° = 15°
   Since the cursor lies on the 18° side between the two graduations 12° and 18°, 3° (one turn of the MIN indicator) should be added to 12°.
   MIN: 240' = 2°
   Although 240' is 4°, the actual tilt angle is 2°.
   Fig. 4.8b shows the tilt angle of 7° in the + direction, i.e.,
   DEG: 6°
   No addition should be made to 6° since the cursor lies on the 6° side between the two graduations 6° and 12°.
   MIN: 120' = 1°
   Although 120' is 2°, the actual tilt angle is 1°.

Use the "RESULTANT TILT ANGLE AND AZIMUTH CHART DIAGRAMS" in the EM-BST instruction manual instead of Fig. 4.9 in this manial.

合成角および方位角度表

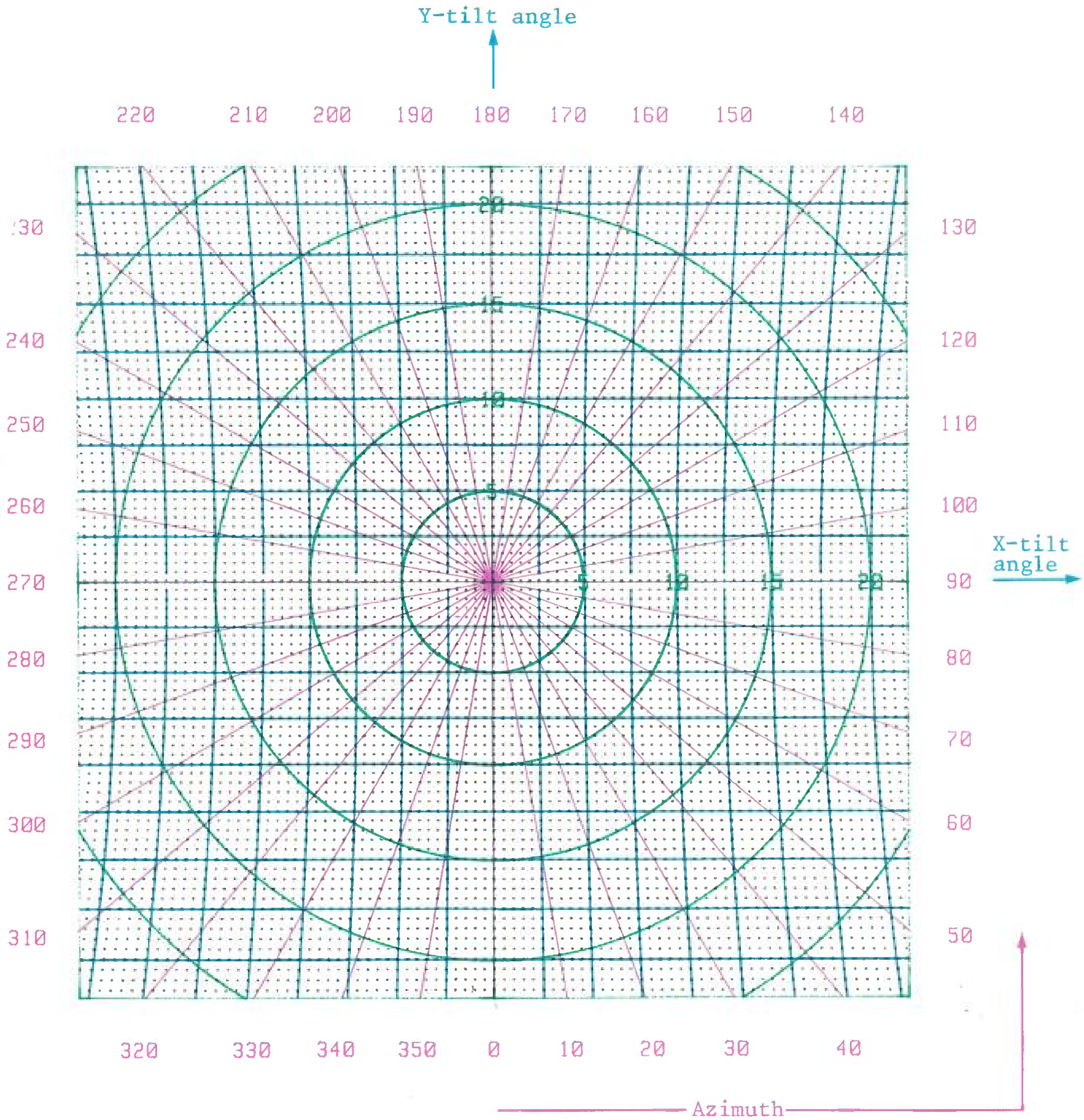
X傾斜角とY傾斜角を下表にあてはめれば，合成角と方位角がわかります。たとえば，X傾斜角が+35°でY傾斜角が−30°の場合は，合成角は45°，方位角は54.5°になります。



40° tilt

RESULTANT TILT ANGLE AND AZIMUTH CHART DIAGRAMS

After obtaining X- and Y-tilt angles, the resultant tilt angle and azimuth can be read off from the diagram below. Assuming that the X- and Y-tilt angles are +17.5° and -10°, respectively, the resultant angle is 20° and the azimuth is 61°.



15° tilt

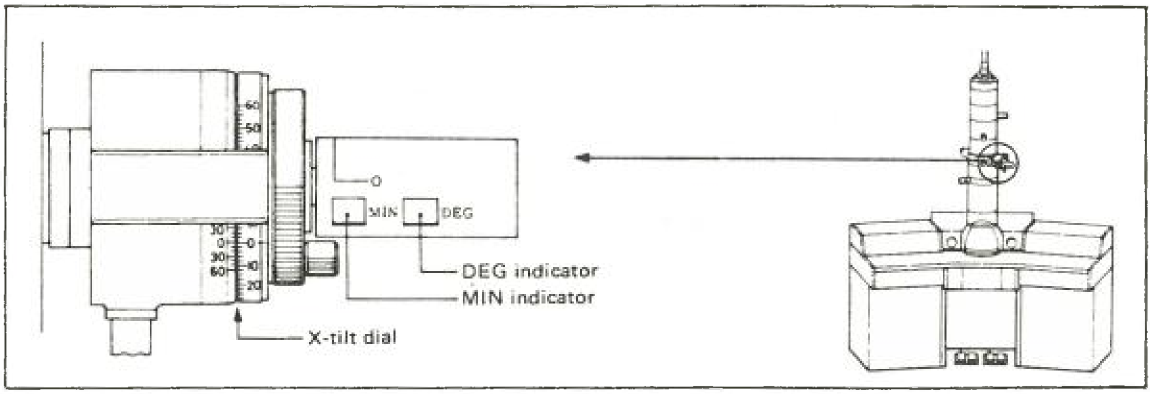


Fig. 4.1 X-tilt dial and Y-tilt indicators

4.2 Specimen exchange

1. Remove the specimen holder stand from the specimen holder box and mount specimen exchange mount B on specimen exchange mount A (see Fig. 4.2).

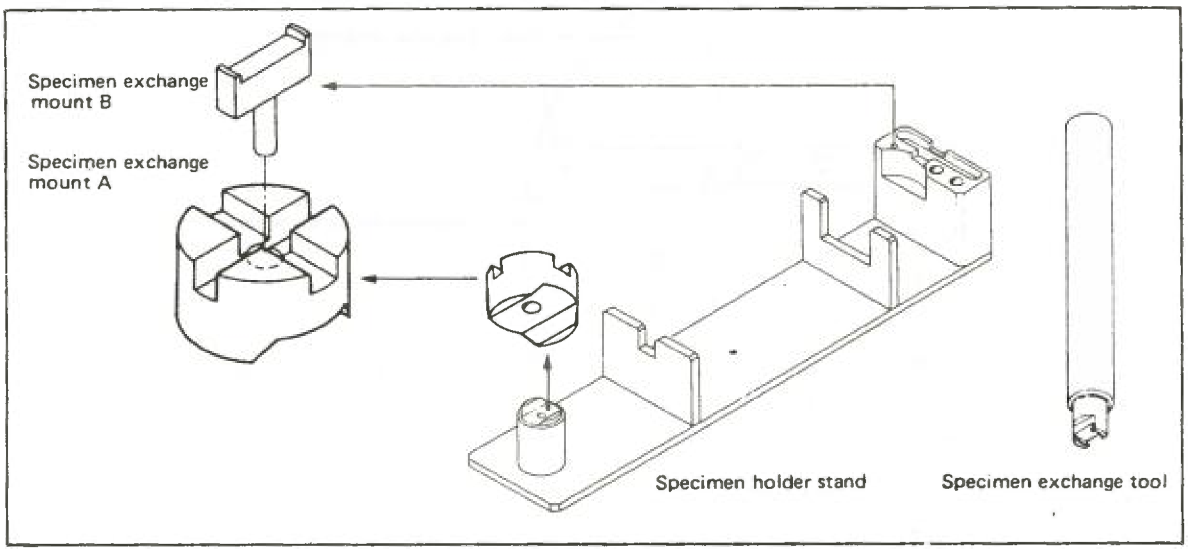


Fig. 4.2 Specimen exchange mounts

2. Place specimen exchange mount A in the specimen holder stand so that mount B is oriented as shown in Fig. 4.3.

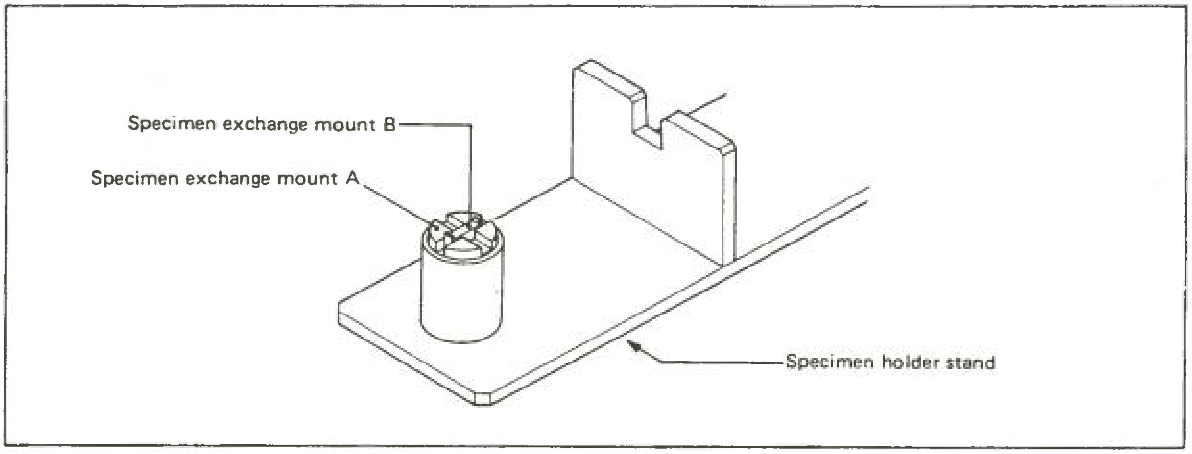


Fig. 4.3 Mounting the specimen exchange mounts

3. Place the specimen holder on the specimen holder stand with the holder shaft pin facing downward as shown in Fig. 4.4.

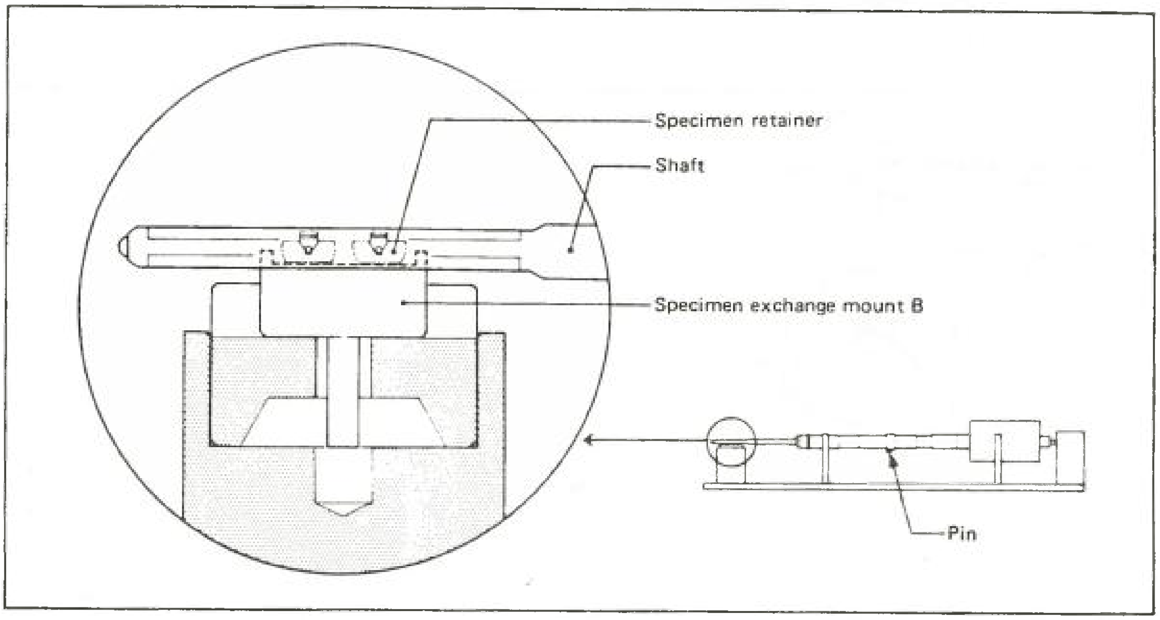


Fig. 4.4 Mounting the specimen holder on the holder stand

4. Remove the used specimen from the specimen holder as follows (Fig. 4.5):
   a. Orientate the clawed tip of the specimen exchange tool in the specimen retainer so that the two claws do not align with the arms of the specimen clamp (Fig. 4.5a), then, while lightly applying downward pressure on the tool, turn the tool so that it engages

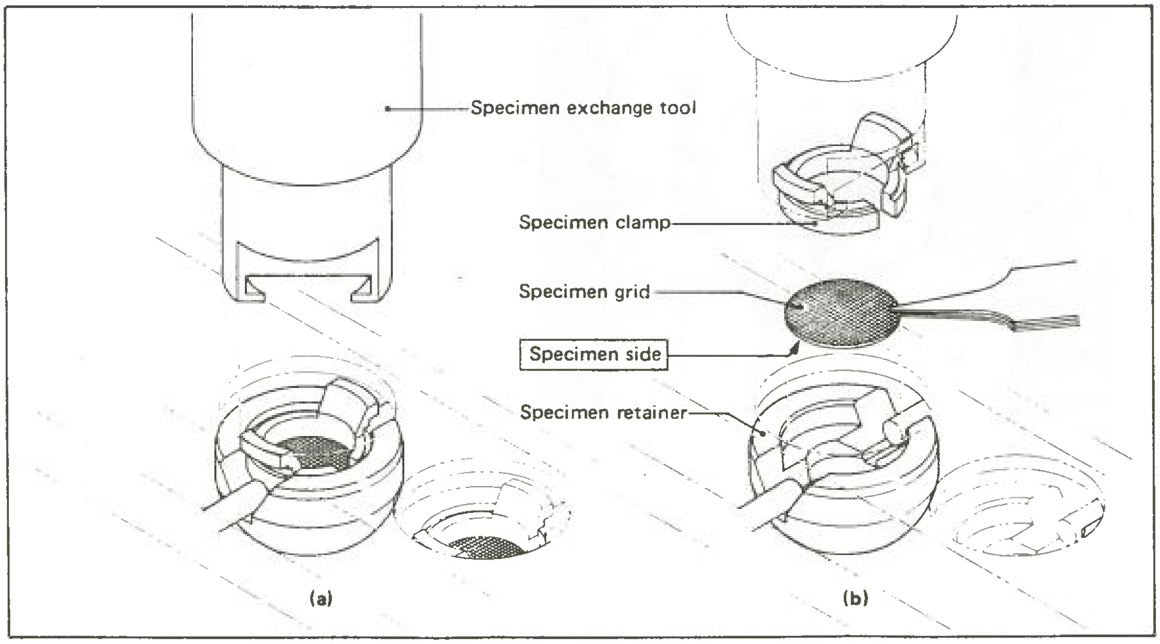


Fig. 4.5 Specimen exchange

with the tipped rim of the clamp and remove the clamp by lifting the tool straight up (Fig. 4.5b).

b. Remove the specimen holder from the holder stand, and the specimen from the holder by turning the holder upside down.
c. Return the specimen holder to the stand (Fig. 4.4).

5. Load a new specimen in the specimen holder as follows:
   a. Place the specimen grid in the specimen retainer with the specimen facing downward (Fig. 4.5b).
   b. Attach the specimen clamp to the specimen exchange tool and insert the tool into the specimen retainer.
   c. Detach the tool from the clamp by turning the tool sufficiently to disengage it from tipped rim of the clamp. The specimen is now secured in the specimen retainer.
   d. Make a note of the specimens in the 1 and 2 specimen retainers.

4.3 Inserting the specimen holder into the column

1. Limit the X-tilt angle as follows:
   a. Turn the X-tilt speed control knob fully clockwise and set the X-tilt dial to 0° by operating the X-pedal switches.
   b. Set the two X-tilt angle limiting screws (Fig. 4.6) to 25°.
2. Confirm the following:
   a. That the V7 of the JEM-1200EX is closed, or the HIGH and AIRLOCK OPEN lamps of the JEM-100/200CX are lit.

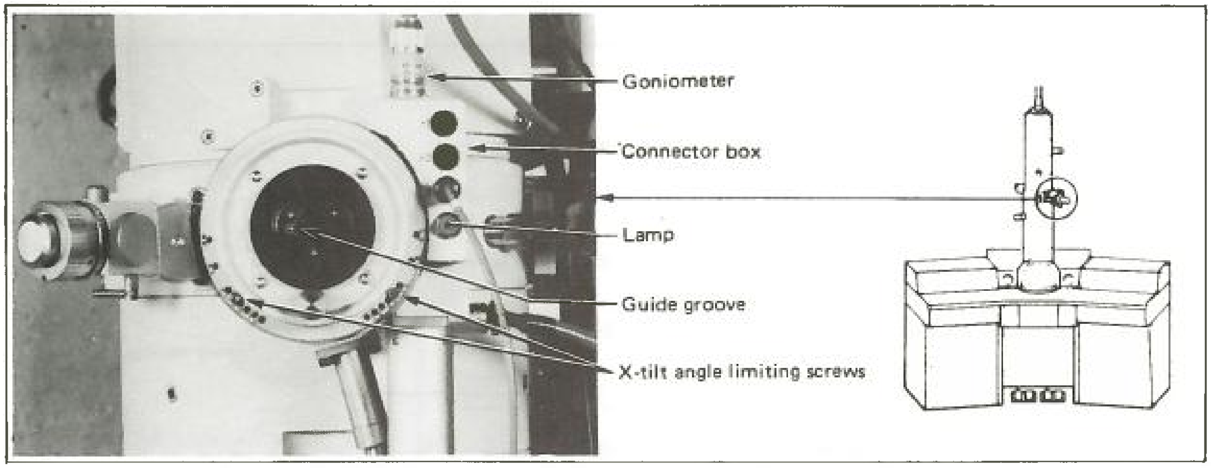


Fig. 4.6 Goniometer

b. That the FILAMENT (EMISSION) knob is set at OFF.
3. After checking that there is no dirt or dust on the specimen holder O-ring, align the specimen holder guide pin with the goniometer guide groove (Fig. 4.6), push the holder into the goniometer as far as it will go and hold it there until the connector box lamp (which lights up indicating the commencement of goniometer evacuation) goes out.
4. When the connector box lamp goes out indicating that goniometer evacuation is complete, turn the specimen holder fully clockwise and push it in fully.
5. Connect the holder cable to socket H1 on the connector box.
6. Set the specimen number indicator (Fig. 4.7) to the desired number with the specimen selector.

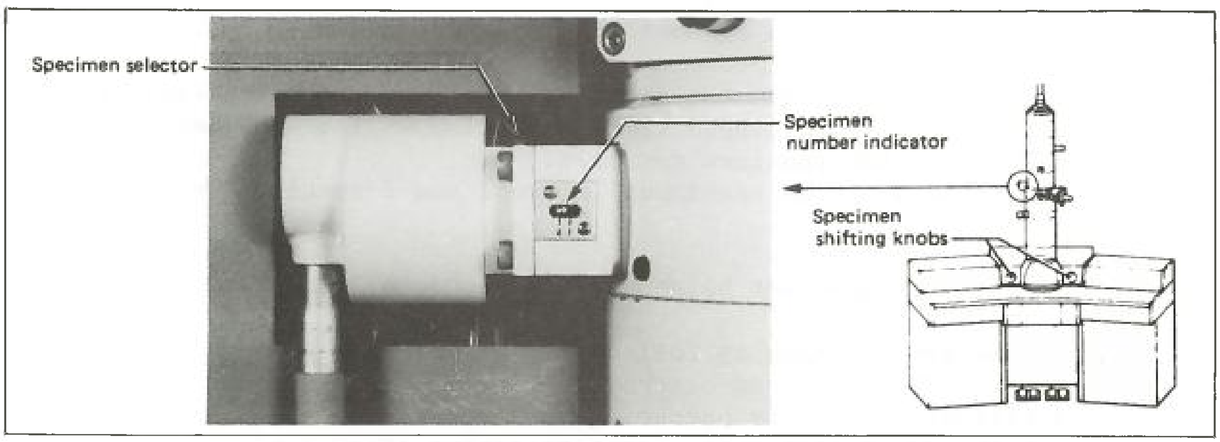


Fig. 4.7 Specimen selecting device

4.4 Tilting the specimen

This describes how to carry out Y-tilting. See the microscope's instruction manual (in case of 100CX, see SEG instru. manual) concerning X-tilting.

1. Select the specimen tilting speed with the Y-tilt speed control knob.
2. Tilt the specimen by operating the pedal switches while observing the image. To select the desired field of view, use the specimen shifting knobs.
3. Read off the Y-tilt angle from the DEG and MIN indicators on the specimen holder.

   Reading off the Y-tilt angle
   One graduation of the DEG indicator corresponds to 6 degrees and one graduation of the MIN indicator corresponds to 10 minutes. The direction of tilt is assumed to be + or - when the specimen retainer is turned counterclockwise or clockwise viewed from the front of the specimen chamber. The red digits are used for + rotation and the black digits for - rotation. For example if the DEG and MIN indicators read as shown in Fig. 4.8a, that is

   DEG: 12°
   MIN: 240' = 4°

   the Y-tilt angle is 16° in the - direction.
   If the DEG and MIN indicators read as shown in Fig. 4.8b, that is

   DEG: 6°
   MIN: 120' = 2°

   the Y-tilt angle is 8° in the + direction.
4. Read off the resultant specimen tilt angle and azimuth from the chart diagram (Fig. 4.9). For example, if the X-tilt angle is -25° and the Y-tilt angle is -15°, the resultant tilt angle and azimuth are about 27.5° and 299°, respectively.

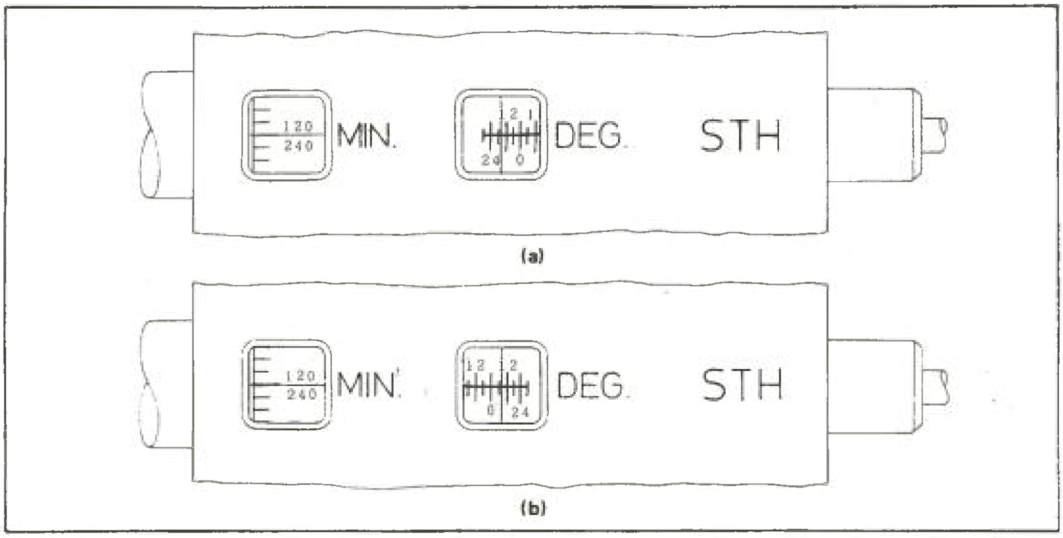
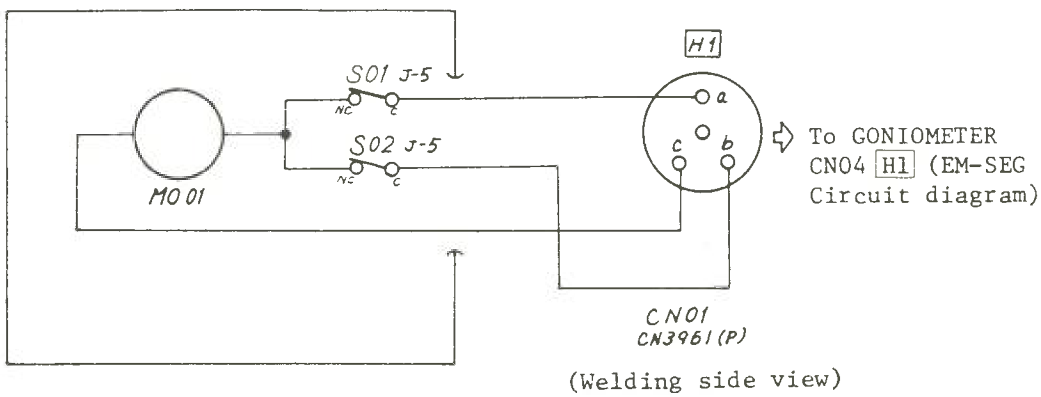


Fig. 4.8 Y-tilt indicators



SPECIMEN TILT AND ROTATION HOLDER	MT280101

INSTRUCTIONS

EM-SDT10

STEP DOWN TRANSFORMER

No. IEM1200EX-SDT10
(EM565001)

1. SPECIFICATIONS

. Input voltage:	Single phase, 200/210/220/230/240/ V, 50/60 Hz
. Output voltage:	Single phase, 100 V and 200 V, 1kVA
. Dimensions:	226 mm (W) × 240mm (D) × 230mm (H)
. Weight:	20 kg
. Rush current:	Rated current × 3 (for not longer than 1 sec.)

2. INSTALLATION

1. Connect the transformer's primary side to a power distributor. The terminal voltage should be same as the power distributor voltage.
2. Connect the load to the transformer's secondary side.
   Notes: 1. If the load is connected to 0-100 V terminal, up to 10 A can be supplied; if connected to 0-200 V terminal, up to 20 A.
   2. When using 0-100 V and 0-200 V terminals at the same time, the total power should not exceed 1 kVA.

COMPONENTS LIST (BE520)

K-NO. 82,03,08
606101608(00) MODEL EM-SDT10 EM565001-

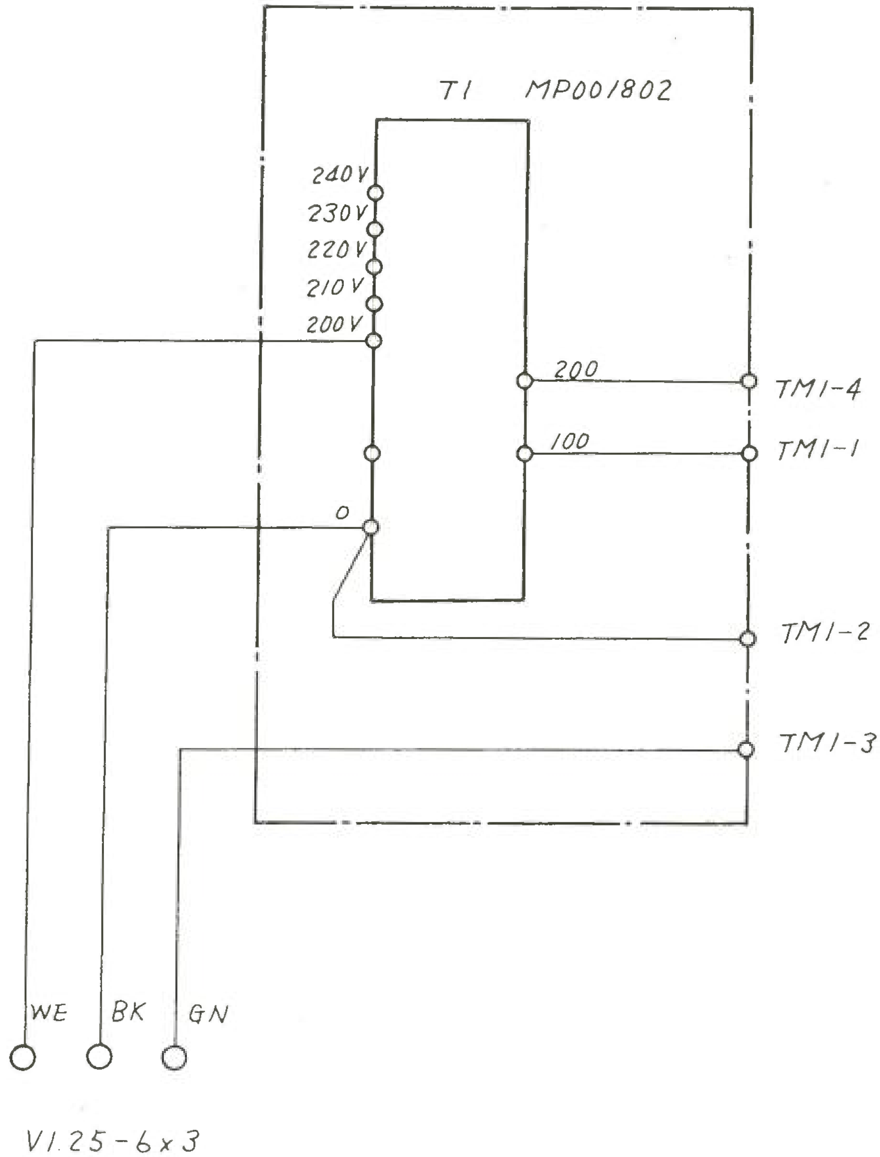
PART NO.	DESCRIPTION		PAGE
606112847	6C6112847(CC)-CO 4	CPRSR TRANS	1

N O T I C E

In order to keep abreast of the latest technological developments, the circuits and circuit components constituting your recently delivered instrument may differ slightly from those as indicated in your book of circuit diagrams.

この電気回路図を使用していただくにあたって

最新のエレクトロニクスが要求される理科学機器の性質上，本装置では常に改良が加えられています。したがって，貴所に納入されました装置の実際の回路とこの回路図では数値その他に多少の差異が生ずることがありますが，その点御理解の上御了承願います。



CPRSR TRANS	606112847